ACTA Mineralogica Petrographica

Acta Mineralogica-Petrographica, Field Guide Series, Vol. 23, pp. 1–50.

Classic skarn localities of Romania: Contact metamorphism and mineralization related to Late Cretaceous magmatism

Gheorghe Ilinca

Department of Mineralogy, Faculty of Geology and Geophysics, University of Bucharest, Bd. N. Bălcescu, 1, 010041, Sector 1, Bucharest, Romania; ilinca@geo.edu.ro

Table of contents

1. Introduction to the geology and mineral deposits of the area visited

The aim of this trip is to observe skarn and mineralization occurrences related to the thermal metamorphic and metasomatic areas around a series of Late Cretaceous-Eocene magmatic massifs, known under the collective term of "banatites". These igneous rocks have been recognized since the 19th century, when Bernhard von Cotta (1864) was the first to describe a suite of consanguineous magmatic rocks occurring as either shallow intrusions or subvolcanic bodies, not older than Cretaceous sedimentary formations, yet younger than the "basalts[1]". The name "banatites", firstly used by Cotta, reflects their *locus typicus*, that is, Banat region, covering parts of the south-western Romania and eastern Serbia. The same author wrote about the mineral and textural diversity of banatites, about the extensive contact metamorphism taking place in their aureoles and about the inherent difficulties of their classification.

Owing to its geographical determination, the term "banatites" has been preserved and extensively used, mostly for its meaning as a petrological province, rather than for depicting a rock typology (*e.g.* Codarcea, 1931; Giuşcă *et al.*, 1965, 1966; Cioflica & Vlad, 1973b, 1977; Giuşcă, 1974; Rădulescu & Dimitrescu, 1982; Ştefan *et al.*, 1985 *etc.*). Other authors preferred time-related terms such as "Laramian" (Cioflica & Vlad, 1973b, 1977), "Late Cretaceous" or "Late Cretaceous-Early Tertiary" magmatites (*e.g.* Bocaletti *et al.*, 1978; Cioflica *et al.*, 1997; Downes *et al.*, 1995b), or involved a geotectonic and geographic significance: "Banat-Srednogorie belt" or "rift" (Popov, 1981, 1987),"Banatitic Magmatic and Metallogenic Belt – BMMB" (Berza *et al.*1998) or " Apuseni-Banat-Timok-Srednogorie Belt – ABTS" (Popov *et al.*, 2000). For the purposes of this guide – dealing both with the primary magmatic products and with their connected contact metamorphism counterparts: skarns, ore deposits, hydrothermal alterations – the banatites will be hereafter referred to, according to Berza *et al.* (1998).

Ever since their first description by Cotta, in 1864, but especially during the last few decades, banatites have drawn considerable interest in their petrology, age, structural-tectonic significance, as well as their related skarn, porphyry-copper and hydrothermal ore deposits.

The itinerary of this trip includes almost the entire north-south extension of the BMMB in Romania. The belt intersects numerous and extremely diverse regional types of sedimentary and metamorphic formations (Figs. 1 and 2). Therefore, in this introductory part, with the exception of a very brief presentation of the overall geology of Romania, only the general features of the banatites, skarns and related mineralization will be described. Other facets of surrounding geologies will be dealt with separately, for each field stop.

1.1 Overview of the geological setting of banatites

1.1.1 General features

The geology of Romania (Fig. 2), at least in what concerns the outcropping formations, is dominated by the Carpathian chain and the Apuseni Mountains, separated from the former by the

[1] Most probably the "basalts" quoted by von Cotta are those from Lucareţ, Şanoviţa and Gătaia (see section below). For the first two occurrences, Downes *et al.* (1995a) established an age between 2.52 and 2.64 Ma, *i.e.*, Upper Pliocene.

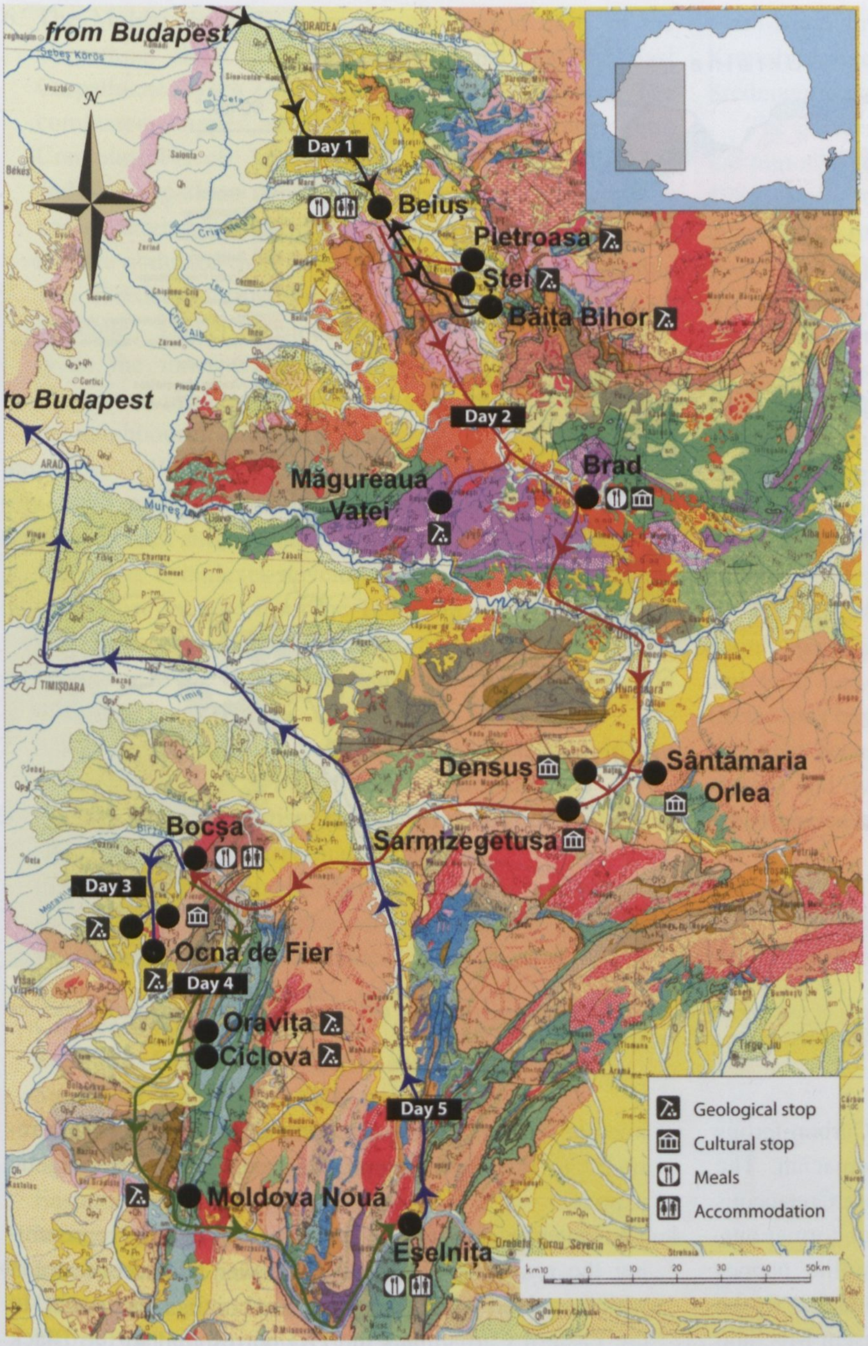


Fig. 1. Fragment of the geological map of Romania (Săndulescu *et al.*, 1978) with the RO5 field trip route following the north-south extension of the Banatitic Magmatic and Metallogenetic Belt.

formations. The Romanian portion of the Carpathian chain form a Z-like thrust and fold belt, curved from N–S to E–W and enclosing the Apuseni Mountains outcrop. The chain gained the present form during the Alpine orogeny as a result of Cretaceous-Cenozoic convergence and collision between the European and Apulian (African) plates, which caused the suture of the Tethys and other oceans (Săndulescu & Visarion, 2000; Dupont *et al.*, 2002).

Overall collision movements were directed eastwards in the Eastern Carpathians (Săndulescu, 1984), and to the south and east in the Southern Carpathians, respectively (Berza *et al.*, 1998), and involved significant remnants of ocean crust and strongly deformed continental margins. Large post-tectogenetic covers develop above the deformed units of the inner orogenic zones in Upper Cretaceous and/or Paleogene. The Transylvanian and Pannonian basins are two Neogene molassic depressions which overlie important parts of the inner zones and their post-tectonic covers. The outer margins of the Carpathian orogen are covered by an elongated Neogene molassic foredeep. Important subduction processes developed in Upper Cretaceous-Paleocene and in Neogene, resulted in two calc-alkaline magmatic arcs (Săndulescu, 1994).

The overall tectonics and geodynamic features of the Carpathian chain in relation with the Apuseni Mountains and their foredeeps and forelands have been described by Săndulescu (1984, 1994), under a concept centred over a so-called Main Tethyan Suture Zone (MTSZ), which represents a relic feature of the Tethys oceanic crust. The MTSZ connects the Vardar Zone with the Pieniny Klippen belt, located in the north-west and representing a part of the larger Piemont Ocean. The author divided the entire orogenic chain into several tectonic units comprising complex paleogeographical features and nappe structures. Some of these units will be referred thereafter and their terminology will be later used in explaining the geotectonic setting of the BMMB. Starting from the inner most parts of the Carpathian-Apuseni orogen, these units are as follows:

Transylvanian Basin. The foreland of the orogenic areas includes the Moesian, East European and Scythian platforms, as well as the North Dobrogea orogen. The geological history is extremely complex, with rocks ranging in age from Precambrian to Neogene, and bearing signs of multiple and often superimposed generations of Mesozoic rifting and collisional events in various stages of Cretaceous and Cenozoic (*e.g.* Zimmermann *et al.*, 2008). These events resulted in an extremely complicated pattern of nappe structures, large regional metamorphic belts, significant areas with Mesozoic and Cenozoic magmatites and a wide range of sedimentary

1. The Inner Dacides (ID) – correspond to parts of the Foreapulian block and are located to the west and north of the MTSZ. They consist of a north and northeast vergent nappe system outcropping in the north part of the Apuseni Mts. (Northern Apusenides). The unit comprises metamorphic rocks and granites overlain by a succession of

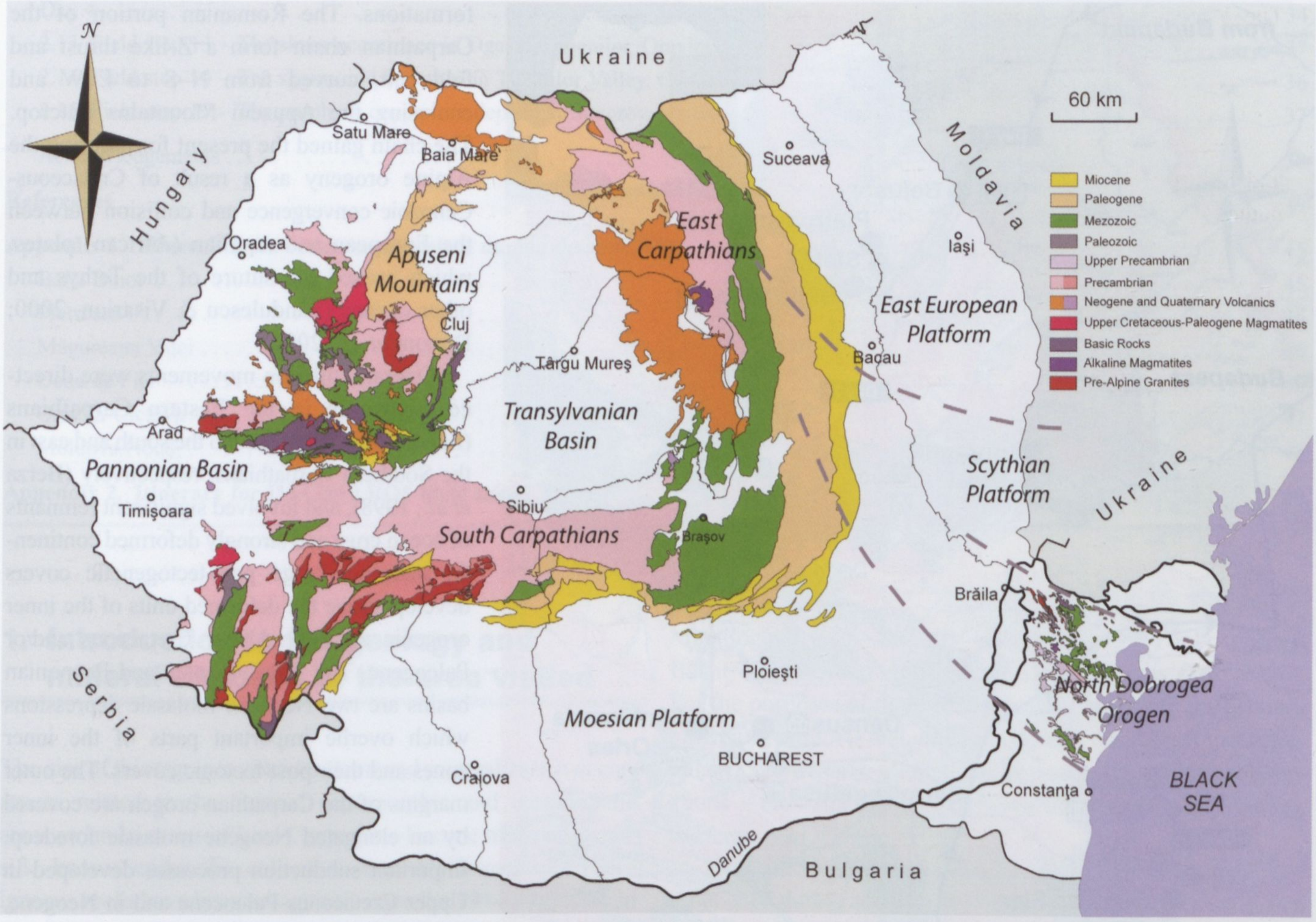


Fig. 2. The geological map of Romania with the main groups of outcropping formations and the major tectonic and physiographic units (modified after the scalable map compiled by the Geological Institute of Romania based on Săndulescu *et al.*,1978).

sedimentary formations ranging from Upper Carboniferous and Permian to Lower Triassic and pre-Coniacian. The post tectonic cover is represented by Upper Cretaceous deposits and sparse Paleogene epicontinental formations.

2. The Transylvanides – consist of two ophiolite nappes occurring in the Southern Apuseni Mts. obducted to the north-west, over the ID of the Northern Apuseni Mts. and to the east over the basement nappes of the central Eastern Carpathians, respectively. Thus, the Transylvanides are the upper most nappe structures in the Apuseni Mts. and in the Eastern Carpathians. Two avoid confusion among the two nappes, some authors prefer the term Mureş Zone to designate the Transylvanides from the Apuseni Mts. (*e.g.* Ionescu *et al.*, 2009; Hoeck *et al.*, 2009). These authors regard the Mesozoic ophiolites and related rocks occurring on top of the Eastern Carpathians as not being related to the Jurassic Mureş Zone.
3. The Median Dacides (MD) – occupy the opposite side of the MTSZ with respect to the ID. The MD outcrop in the central part of the Eastern Carpathians and over large areas of the Southern Carpathians. They consist of basement-shearing nappes with crystalline formations and sedimentary covers. In the Southern Carpathians they correspond to the Getic Nappe overthrust by the Supragetic nappes.
4. The Outer Dacides (OD) – group a strip of units representing the remnants of a Jurassic-Lower Cretaceous ocean which evolved within the European continental margin. In the Eastern Carpathians the OD correspond to the Black Flysch, Baraolt and Ceahlău nappes, whereas in the Southern Carpathians, they form the Severin Nappe which is trapped between the MD (Getic Nappe) and the Marginal Dacides (Danubicum – see below). This paleorift is also known as the Severin Ocean (*e.g.* Ciobanu *et al.*, 2002) – recognized to include Măgura, Ceahlău, Severin, Krajina and Trojan nappes and represents a satellite suture with respect to the MTSZ.
5. The Marginal Dacides (MAD) – or Danubicum, occur as a large half-window underneath the Getic and Severin nappes. They mainly consist of crystalline formations (Precambrian mesometamorphic rocks with numerous granite to diorite intrusions of Late Precambrian and Early Cambrian age) and a sedimentary cover with Permian molasse and Mesozoic carbonate formations.

6. The Moldavides (M) – are the outer most units of the Carpathian chain. They cover major parts of the East Carpathians Flysch Zone, excepting of the OD nappes. The component nappes are – from the inner to outer side: Convolute Flysch, Macla, Audia, Tarcău, Marginal Folds and Subcarpathian nappes. They consist of allochtonous bodies ranging Lower Cretaceous up to the Lower Miocene and are obducted over foreland areas.
7. The foredeep formations consist of Upper Miocene – Pliocene – Lower Pleistocene molasses originating entirely in the inner Carpathian areas. They outborder the Carpathian chain to the east and south and cover parts of the neighbouring platforms.

Săndulescu (1994) has summarized also the Mesozoic and Cenozoic magmatic activity which took place in the Carpathian area and in Apuseni Mts.:

1. Ophiolitic complexes developed between Middle Triassic and Upper Jurassic from the Tethysian oceanic crust (still preserved in the Transylvanides), and Jurassic ophiolites occurring in the Outer Dacidian paleorift (Severin Nappe of the OD).
2. Alkaline magmatism of Jurassic age developed in the extending margins of the Outer Dacidian paleorift.
3. Calc-alkaline magmatism developed during the compressive stages of the Carpathians, and in relation with subduction processes. Two main calc-alkaline periods were documented: a) "Banatites" – predominantly intrusive, Upper Cretaceous–Paleocene, in the Southern Carpathians (Getic and Supragetic areas of the MD) and in the ID parts of Apuseni Mts., and b) Neogene volcanics, occurring in the Eastern Carpathians and Apuseni Mts.
4. Intracontinental basalts of Pliocene-Quaternary age (in Perşani Mts. and Mureş Valley), in connection with deep (transcrustal) faults

1.1.2 The regional extension of BMMB

The BMMB represents a series of discontinuous magmatic and metallogenic districts that are discordant over the mid-Cretaceous nappe structures (Cioflica & Vlad, 1973; Ciobanu *et al.*, 2002). The belt extends over approximately 900 km in length and around 30 to 70 km in width. It has a north-east to south-west trend over Apuseni Mts. and Southern Carpathians, it aligns to a north-south direction over eastern Serbia (Timok and Ridanji-Krepoljin zones), and bends widely to the east, through the Srednogorie area, reaching the shores of the Black Sea (Fig. 3).

The northern most occurrences are in Apuseni Mts., with the plutonic-volcanic Vlădeasa massif (Istrate, 1978; Ştefan, 1980; Ştefan *et al.*, 1992) and numerous small apexes and dykes, often rooted in large and deep plutonic bodies (Andrei *et al.*, 1989), spread over large areas at Cornițel-Borod, Gilău, Budureasa, Pietroasa, Băişoara, Valea Seacă, Băița Bihor, Brusturi, Căzăneşti, Măgureaua Vaței, (Fig. 4) and intersecting pre-Alpine basement and Mesozoic formations of the Mid-Cretaceous nappe structures (Berza *et al.*, 1998). Apart from prevalent andesites, dacites, ignimbritic rhyolites and banded biotite-bearing rhyolites of the Vlădeasa "taphrolite" (Giuşcă, 1950), granodiorite-granite intrusions are predominant among other occurrences in the Apuseni Mts., with subordinate quartz monzodiorites and quartz diorites (Ştefan *et al.*, 1992).

South of Mureş Valley, the belt continues with swarms of mainly intrusive, small magmatic bodies and larger intrusions, and with only sparse volcanic formations as those in the Cretaceous basins of the Poiana Ruscă Mts.

Other occurrences consisting of dioritic and granodioritic plutons and dyke swarms of andesites, dacites and rhyolites, accompanied by lamprophyric dykes are those at Tincova and

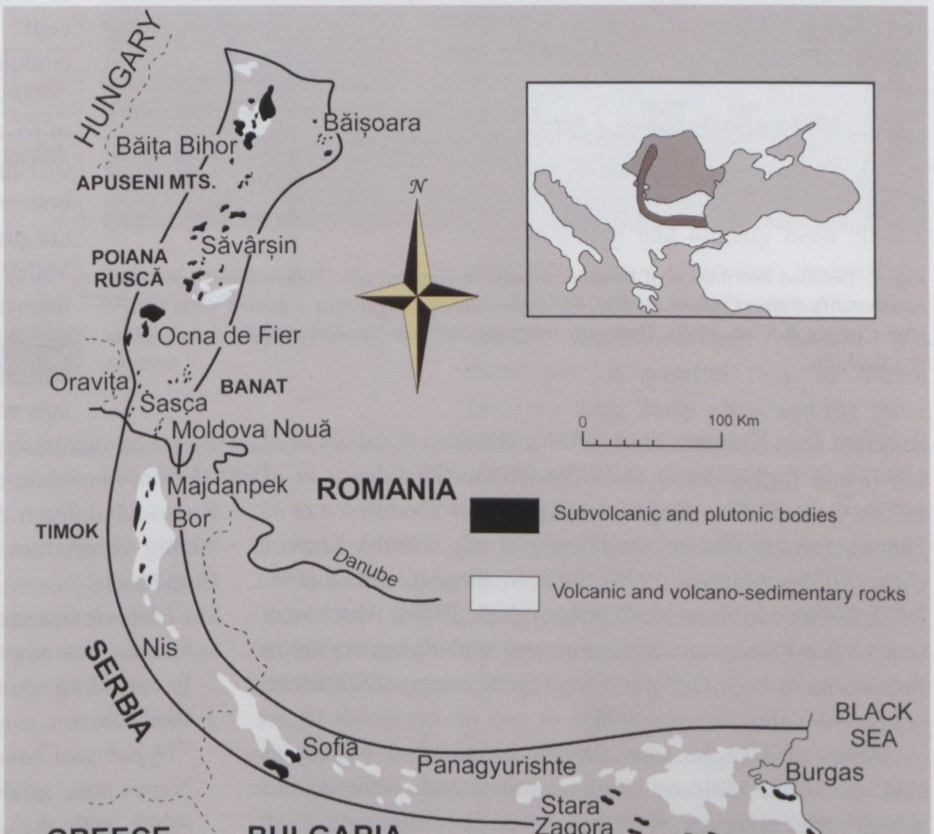


Fig. 3. The extension of the Banatitic Magmatic and Metallogenic Belt over Romania, Eastern Serbia and Bulgaria (with dark gray in the inset and with heavy outline in the map). Simplified after Cioflica & Vlad (1973). A more detailed distribution of the banatite massifs in Romania is given in Fig. 4.

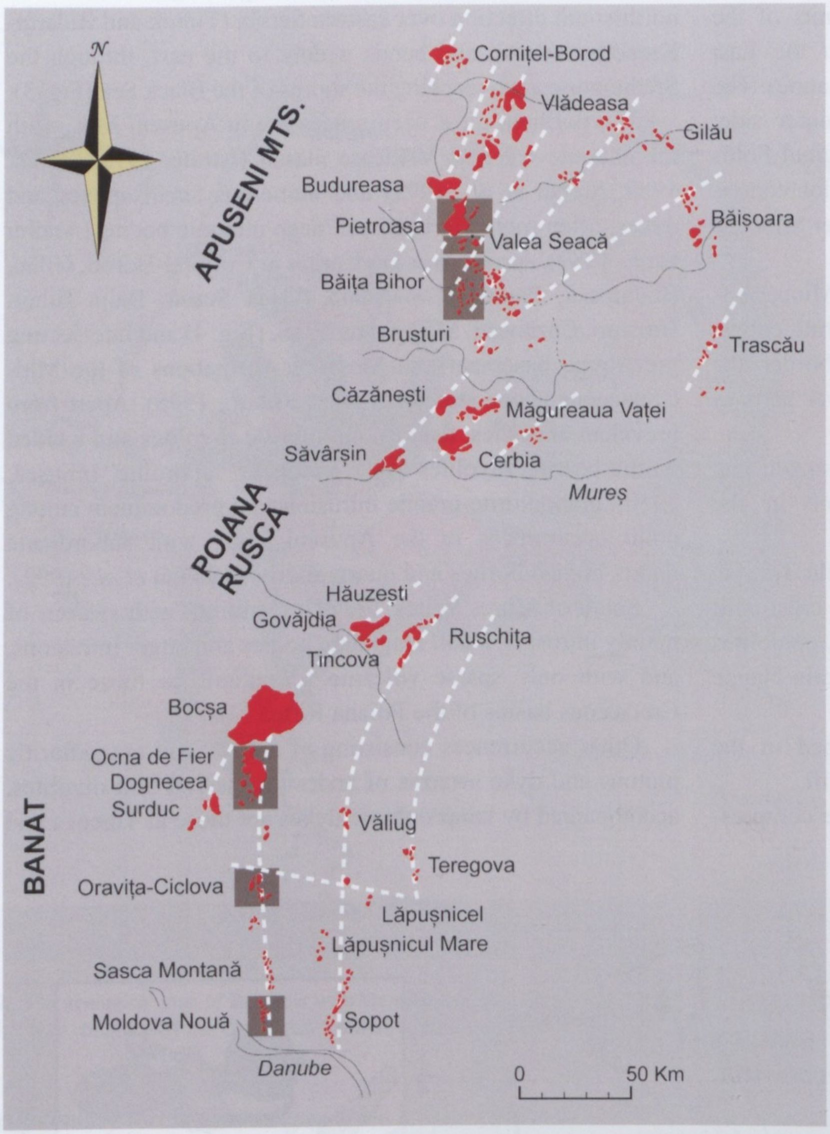


Fig. 4. Detailed distribution of banatitic massifs in Apuseni Mts, Poiana Ruscă and Banat area (modified after Cioflica & Vlad, 1974; petrogenetic alignments – dashed white lines – after Cioflica & Vlad, 1980). Dark gray rectangles indicate banatitic massifs visited during this field trip.

Ruschiţa (*e.g.* Kräutner *et al.*, 1986), Hăuzeşti (Cioflica *et al.*, 1994) and further south at Bocşa (Russo-Săndulescu *et al.*, 1978), Ocna de Fier–Dognecea (*e.g.* Russo-Săndulescu *et al.*, 1986a), Surduc (Russo-Săndulescu *et al.*, 1986b), Oraviţa-Ciclova (Gheorghiţescu, 1975), Sasca Montană (Constantinescu, 1977, 1980), Moldova Nouă (Gheorghiţă, 1975), which intersect Upper Palaeozoic, Mesozoic and underlying crystalline formations of both Getic and Supragetic nappes (Năstăseanu *et al.*, 1981, Berza *et al.*, 1998).

South of Danube, the already pronounced hypabyssic character of the Moldova Nouă magmatic body reflects in the sub-volcanic complex of Ridanj-Krepoljin (Karamata *et al.*, 1997; Djordjević *et al.*, 1997, Berza *et al.*, 1998). Eastwards of the plutons described above, banatites occur as dyke swarms and small plutons of porphyritic quartz diorite, monzodiorite or granodiorite, lamprophyres and andesites, at Văliug, Teregova, Lăpuşnicu Mare and Şopot (Gunnesch *et al.*, 1975, 1978; Întorsureanu, 1986; Cioflica *et al.*, 1991, 1993). Such hypabyssic bodies cross crystalline schists of the Getic Nappe basement or Cenomanian-Middle Campanian formations (Năstăseanu *et al.*, 1981). South of the Danube, this zone extends into the volcanic and intrusive complex of the Timok area (Djordjević *et al.*, 1997; Karamata *et al.*, 1997). Attempts were made to ascribe such apparently randomly distributed occurrences to several alignments or magmatic trends, with NE–SW orientation (Giuşcă *et al.*, 1966, Vlad, 1979, Cioflica & Vlad, 1980), (Fig. 4), but they sometimes do not coincide with the trend of larger plutons beneath (Figs. 5 and 6).

The banatites from the south-western part of the Southern Carpathians were ascribed to two main magmatic stages, with strongly distinct petrological characters (Russo-Săndulescu *et al.*, 1984):

A – Coniacian-Maastrichtian stage (K-Ar radiometric ages between 87 and 68 Ma) represented by polyphasic plutons with evidence for the existence of intermediate magma chambers in incipient extensional, yet relatively "quiescent" tectonic regime (gabbros with initial cumulate crystallization).

B – Maastrichtian-Eocene stage (K-Ar ages of 65-42 Ma) well embodied in the northern side of Timiş Valley, in the Poiana Ruscă Mts., where both extrusive and intrusive magmatic outputs are preserved. A large area between the Timiş Valley and the Danube gives evidence for an intensive intrusive activity which apparently lasted for a large period of time. Presumably, volcanism here was either absent or all its products were eroded.

Based on radiometric dating and petrological features collected from magmatic outcrops, boreholes and geophysical data, Russo-Săndulescu & Berza (1979) suggested the following zoning of banatites in the south-western part of the Southern Carpathians

- *"Plutonic banatitic zone"* (PBZ) with two maxima of intrusive magma emplacement in stages A and B, predominantly extending over the Supragetic nappes or slightly beyond their limits.
- *"Hypabissal banatitic zone"* (HBZ) restricted to the Getic Nappe area; small banatitic intrusions generally do not correlate with the deep plutonic distribution inferred from aeromagnetic and gravimetric data (Andrei *et al.*, 1989). K-Ar ages and the relationships with sedimentary formation of Şopot zone, indicate that these magmatites correspond to the B stage.

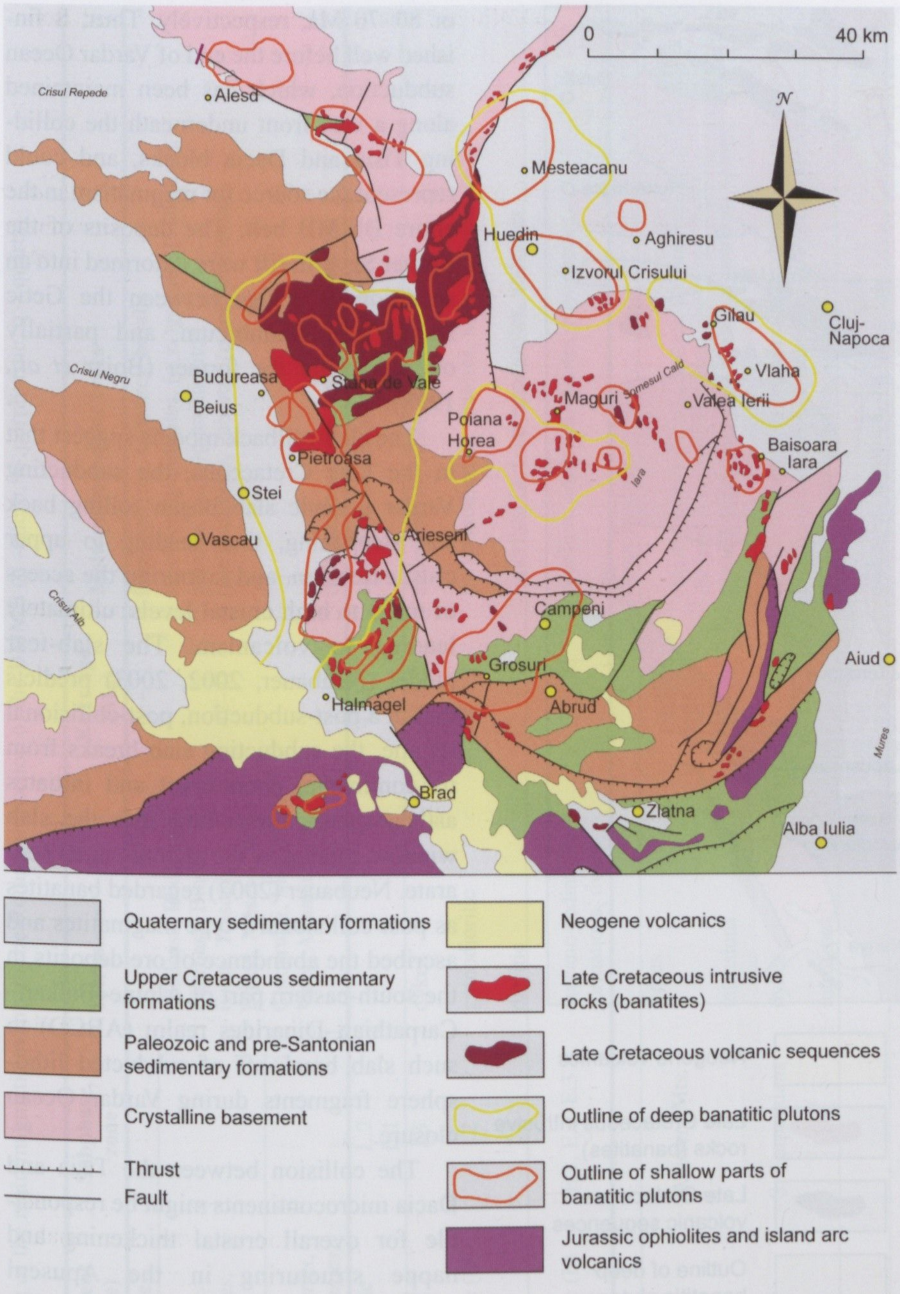


Fig. 5. Simplified map of the Apuseni Mts. with the in-depth development of banatitic plutons, interpreted from aeromagnetic and gravimetric data (redrawn from Andrei *et al.*, 1989).

– *"Volcano-plutonic complex of Poiana Ruscă Mts."* (VPCPR) corresponds to volcano-sedimentary formations in the Rusca Montană basin. Large intrusive bodies and dykes intersect these formations and post-Maastrichtian tectonic contacts (*e.g.* Tincova) may be observed, too.

A synoptical view of the banatite typologies described above is given in Table 1.

1.1.3 Geodynamic setting of banatites

Numerous models have been published in the last decades to explain the formation and the geodynamic significance of the BMMB. Although several mechanisms involving rifting processes have been proposed (*e.g.* Popov 1981, 1987, 1995 and other references quoted by Ciobanu *et al.*, 2002), subduction models have been almost unanimously invoked in relation to the two major ocean sutures within the Carpathian-Balkan orogen: the Vardar Ocean with its Mureş Zone and Transylvanian extensions, and the Severin Ocean with remnants preserved in Măgura, Ceahlău, Severin and Trojan nappes (Fig. 7). However, major disagreement exists among these models, especially in what concerns the direction and timing of subduction.

Comprehensive overviews of such subduction related models are given by Berza *et al.* (1998), Ciobanu *et al.* (2002) and Zimmermann *et al.* (2008). Westward subduction of ocean remnants in the Transylvanian Basin has been invoked for banatites occurring in the ID (North Apuseni Mts. – *e.g.* Rădulescu & Săndulescu 1973, Rădulescu *et al.*, 1993 a.o.). An eastward subduction of the Severin Ocean crust has been used to explain banatite formation in the west part of Southern Carpathians (Rădulescu & Săndulescu, 1973; Bleahu,1976; Russo-Săndulescu & Berza,1979; Vlad, 1997 *etc.*). Boccaletti *et al.* (1974) suggested that by the Early Cretaceous, the Vardar Ocean had already been closed, whereas Late Cretaceous magmatism relates to slab-detachment processes during underthrusting beneath the Rhodopes. A parallel may be drawn between these early ideas and the more recent slab-tear model (see below). Eastward and concomitant northward subduction of ocean crust during Vardar closure has also been proposed (*e.g.* Janković & Jelenković, 1997; Karamata *et al.*, 1999).

Berza *et al.* (1998) were among the first to consider that the banatitic magmas where generated in an extensional regime caused by orogenic collapse affecting the upper crust, through mantle delamination due to slab break-off during the northwards directed Vardar-Axios Ocean subduction between Jurassic and Lower Cretaceous.

By the beginning of this century, ideas of BMMB formation and evolution were dominated by subduction models involving either slab-rollback or slab-tear mechanisms affecting the subduction front of the Vardar Ocean (Zimmermann *et al.*, 2008 and references therein).

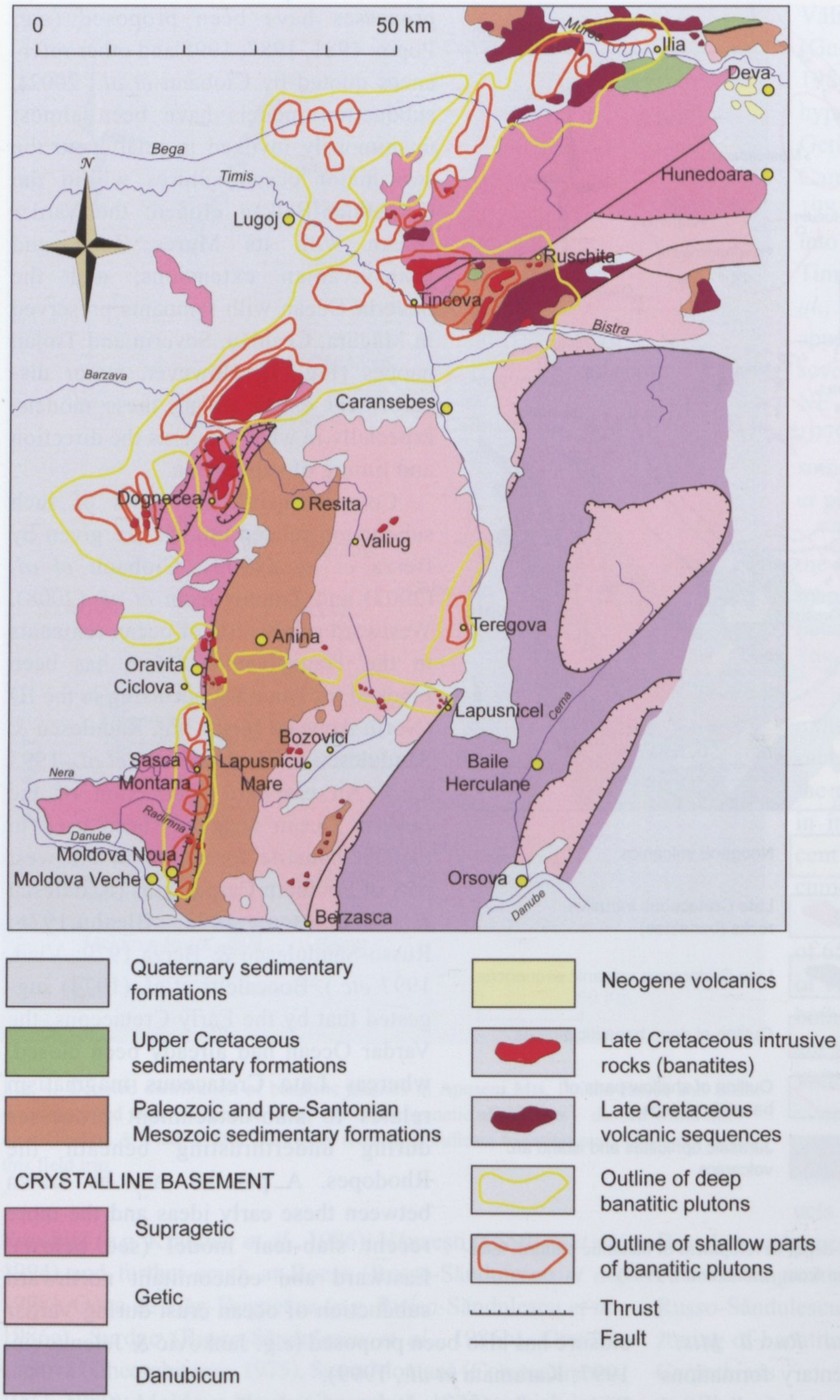


Fig. 6. Simplified map of the south-western part of Southern Carpathians, showing the in-depth distribution of banatite intrusions, interpreted from aeromagnetic and gravimetric data (redrawn from Andrei *et al.*, 1989).

The role of the Severin Ocean in generating subduction related magmatism within the Getic Nappe started to be seen as minor. Based on kinematic and paleomagnetic data collected in the Apuseni Mts. and Southern Carpathians, Bojar *et al.* (1998) and later, Willingshofer (2000) suggested the subduction of the Severin Ocean crust to have terminated around 120 or 80–70 Ma, respectively. Thus, it finished well before the end of Vardar Ocean subduction, which has been maintained along a vast front underneath the colliding Tisia and Dacia blocks, and could represent the source for magmatism in the entire BMMB belt. The deposits of the former Severin rift were deformed into an accretionary wedge between the Getic Nappe and Danubicum, and partially overridden by the former (Bojar *et al.*, 1998).

The slab-rollback models suggest that in the Late Cretaceous, the subducting Vardar oceanic slab began rolling back and steepening, thus leading to upper crust extension, and favouring the access of melts to high crustal levels, ultimately leading to volcanism. The slab-tear model (Neubauer, 2002, 2003) predicts that in a post-subduction, post-collisional regime, the subducting slab breaks from its continental counterpart and initiates asthenospheric upwelling into the slab window created as the tectonic units separate. Neubauer (2002) regarded banatites as post-collisional I-type magmatites and ascribed the abundance of ore deposits in the south-eastern part of Alpine–Balkan–Carpathian–Dinarides realm (ABCD) to such slab break-off of subducted lithosphere fragments during Vardar Ocean closure.

The collision between the Tisia and Dacia microcontinents might be responsible for overall crustal thickening and nappe structuring in the Apuseni Mountains and Southern Carpathians followed by gravitational collapse and formation of collapse Gosau-type basins such as Rusca Montană, Haţeg, Arieş and Borod (*e.g.* Schuller *et al.*, 2009). Newly formed extensional faults could have facilitated magma upwelling in the close vicinity of such basins. (Ciobanu *et al.*, 2002 and references therein).

Paleomagnetic data for banatites occurring both in the Apuseni Mts. and in the Southern Carpathians (Pătraşcu *et al.*, 1992, 1994; Panaiotu 1998; Roşu *et al.*, 2004) indicate clockwise rotations of up to 60-80° with respect to the initial east-west trend at the time of emplacement and before the Cenozoic post-collisional movements which affected Tisia and Dacia blocks (Ciobanu *et al.*, 2002 and references therein).

Table 1. *The succession and timing of the main magmatic events in the Romanian portion of the BMMB (μ -micro, π- porphyritic, q – quartz)*

Unit	Age	Magmatic event (phase, cycle)	Subphase, zone	Intrusions	K-Ar age (Ma)	Main petrographic types
Apuseni Mts. (Ştefan *et al*., 1988)	Upper Ypresian	"Final" cycle			–	lamprophyres, andesites, basalts
	Upper Danian Lower Ypresian	Cycle II *(subvolcanic/ plutonic bodies, dykes)*		Vlădeasa, Budureasa, Pietroasa, Bihor, Gilău, Trascău, Borod, Meseş – Valea Chioarului, Măgureaua Vaţei, Almaşu Mic	47–51	rhyolites, q-andesites, (μ,π-)granites (±alkaline), granites, (μ,π-)granodiorites, (μ,π)q-diorites, gabbros, (q-)monzodiorites
	Upper Maastrichtian Lower Danian	Cycle I *(lavas, pyroclastics, shallow subvolcanics)*			–	rhyolites, andesites, dacites, rhyodacites
Poiana Ruscă Kräutner *et al*., 1986)	Lutetian	Lamprophyric cycle (L)	L.2 L.1		43 ± 2 –	calc-alkaline/alkaline lamprophyres
	Thanetian Danian	Intrusive cycle (I)	I.3	dykes	54 ± 2	andesites, rhyolites, dacites
			I.2	granodioritic	64 ± 2	(π-)granodiorites, granites, monzodiorites, aplites
			I.1	dioritic	–	μdiorites, (μ,π-)monzodiorites, andesites
	Upper Maastrichtian Danian	Extrusive cycle (E)	E.1, E.2, E.3	volcano-sedimentary formations, dykes	65 ± 2	rhyolites, andesites, dacites, rhyodacites
Apuseni Mts. and Banat (Cioflica *et al*., 1992)	Lower Eocene	Stage 4			43	lamprophyres
	Paleocene	Stage 3	Apuseni Mts.	dykes		rhyolites, rhyodacites, aplites, μπ-granites, (μ,π-)diorites, dacites, (m,p-)granodiorites, andesites, basalts;
				intrusions	65–70	granodiorites, monzodiorites, (μ-)granites, aplites;
			S. Carpathians	dykes		(μ)π-monzodiorites, πμ-diorites, andesites, μπ-granites, aplites;
				intrusions		(q-)monzodiorites, (q-)diorites, granodiorites, granites, aplites
	Upper Maastrichtian Lower Paleocene	Stage 2			–	andesites, rhyolites, dacites
	Coniacian Maastrichtian	Stage 1			67–87	gabbros, monzodiorites, q-monzonites, syenites
Banat (Russo-Săndulescu, 1993)	Maastrichtian-Paleogene	B.III	HBZ PBZ	post-intrusive dykes	–	rhyolitic-granophyres, andesites
		B.II	HBZ	Lăpuşnicu Mare, Purcariu-Nasovăţ, Teregova	45–65	πq-monzodiorites, π-granodiorites
			PBZ	Sasca-Moldova Nouă, Oraviţa-Ciclova, Bocşa$_3$-Ocna de Fier–Dognecea Surduc$_3$	– 42–62 48–65 55–62 –	granodiorites ± tonalites
		B.I	PBZ	Ciclova Ocna de Fier	–	q-monzodiorites, diorites, gabbros
	Coniacian–Maastrichtian	A.II	PBZ 68	Bocşa$_2$ Surduc$_2$	80 68	granites, monzonites, potassic syenites
		A.I.	PBZ	Bocşa$_1$ Surduc$_1$	81 75–68	monzodiorites w. gabbro-diorites banding
			PBZ			layered (nodule) cumulates of gabbro and anorthosite

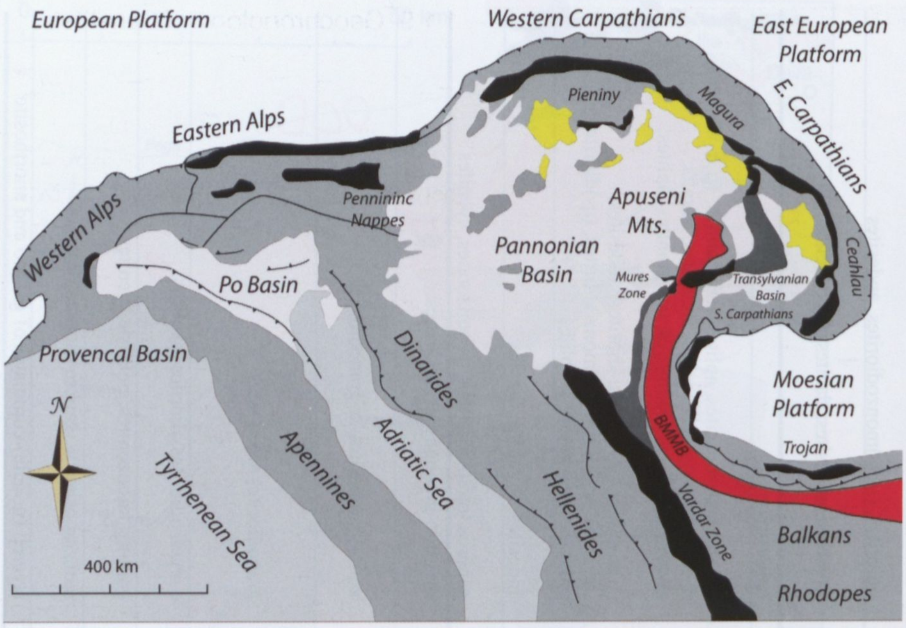


Fig. 7. The Banatitic Magmatic and Metallogenetic Belt in the context of the main geodynamic and structural domains of the Alpine–Balkan–Carpathian–Dinaride orogenic system (Heinrich & Neubauer, 2002).The main suture zones of the Neotethys Ocean are shown in black (outcropping ocean crust remnants) and dark gray (covered suture zones) The red area represents the Banatitic Magmatic and Metallogenetic Belt and the yellow patches, Neogene calc-alkaline volcanics (redrawn from Ciobanu *et al.*, 2002).

1979; Cioflica *et al.*, 1991, 1993, summarized by Berza *et al.*, 1998 and Ciobanu *et al.*, 2002) (Figs. 8, 9, 10). The largest chemical variation is recorded for West Bocşa and Surduc intrusions in northern Banat, but at a constantly high alkali level. A peralkaline trend was found only in the eastern part of Srednogorie. Berza *et al.* (1998) assigned the acidic intrusives to A-type granitoids, originating in the mantle or in deeper crust. For the calc-alkaline bodies in the Southern Apuseni, South Banat, Timok and in the central and western Srednogorie, three stages of evolution have been identified: monzodioritic, dioritic and granodioritic. More evolved granodioritic to granitic trend is recorded in the Northern Apuseni, North Banat and Ridanj-Krepoljin. The alkaline trend is restricted to east and west Srednogorie and western Banat.

REE analyses (Ştefan *et al.*, 1992) point to similar trends in both effusive and intrusive banatites. LREE differentiation and enrichment is higher than in the case of HREE. A negative Eu anomaly correlating with decreasing plagioclase content has also been recorded. Strontium and neodymium isotope data $^{87}Sr/^{86}Sr$ ratios range between 0.7058 and 0.7084 for andesites, 0.7053 and 0.7086 for dacites, 0.7054 and 0.7090 for rhyolites, whereas for Bihor granitic batholiths they reach values around 0.708.

ORG normalized spidergrams (Cioflica *et al.*, 1996,1997; Dupont *et al.*, 2002) show Rb, K, Ba and The enrichment against Ta, Nb, Ce, Hf, Zr, Sm, Y and Yb depletion. The $^{87}Sr/^{86}Sr$ ratios range between 0.703 and 0.706 and $^{143}Nd/^{144}Nd$ between 0.5126 and 0.5128. For comparison, the $^{87}Sr/^{86}Sr$ data published by Janković & Jelenković (1997) and summarized by Ciobanu *et al.* (2002), indicate ratios of 0.705–0.709 for the Apuseni Mountains), 0.703–0.706 for Banat, 0.706–0.710 for Timok and 0.704–0.705 for Srednogorie, respectively.

Dupont *et al.* (2002) report a comprehensive set of geochemical and isotope data from various banatite occurrences in Poiana Ruscă and Banat, inferring no major differences in geochemical trends among calc-alkaline and high-K calc-alkaline intrusions, consistent with the fractional crystallization of parental magmas of similar compositions. Trace-element and isotope data support magma sources situated in the upper mantle and meet the characteristics of subduction zone magmas. Minor variations of Sr and Nd isotopic compositions could indicate slightly heterogeneous mantle or lower crustal sources. No regionally systematic variations of geochemical or isotope compositions suggesting a north-westward deepening of the subduction zone (Vlad, 1979, 1997), could be identified (*op. cit*).

1.1.4 Petrology and geochemistry of banatites

The BMMB is characterized by an extreme petrographic diversity, and of many of the individual outcropping massifs encompass a significant part of this variety. For example, only the west part of Bocşa banatitic massif (Russo-Săndulescu *et al.*, 1972, 1978) contains diorite-gabbros, monzodiorites, (porphyritic) monzonites, (porphyritic) monzogranites, syenites, (porphyritic) granodiorites, aplites, microgranites, andesites and lamprophyres. Thus, a detailed petrographic inventory of each banatite occurrence in the Romanian part of BMMB would be far beyond the scope of this guide.

Effusive banatites encompass a wide range of compositions from rhyolites (Vlădeasa), to alkali basalts (Poiana Ruscă Mts.), but medium and high-K andesites and dacites prevail in all volcanic complexes of the Romanian portion of the BMMB. Intrusive banatites range from gabbros to leucogranites, but the most widespread are (quartz) diorites, granodiorites and (quartz) monzodiorites (Berza *et al.*, 1998; Dupont *et al.*, 2002). Numerous satellite dykes contain basalts, andesites, dacites, rhyolites and relatively diverse lamprophyres.

Banatites are broadly calc-alkaline, with local tholeiitic character. Medium and high-K compositions prevail, but low-K and shoshonitic examples have also been recorded (Istrate, 1978; Ştefan, 1980; Russo-Săndulescu & Berza 1979; Stanisheva-Vassileva, 1980; Dabovski *et al.*, 1991; Ştefan *et al.*, 1992; Gheorghiţescu, 1975; Constantinescu, 1977; Russo-Săndulescu *et al.*, 1978, 1986a,b; Russo-Săndulescu & Berza,

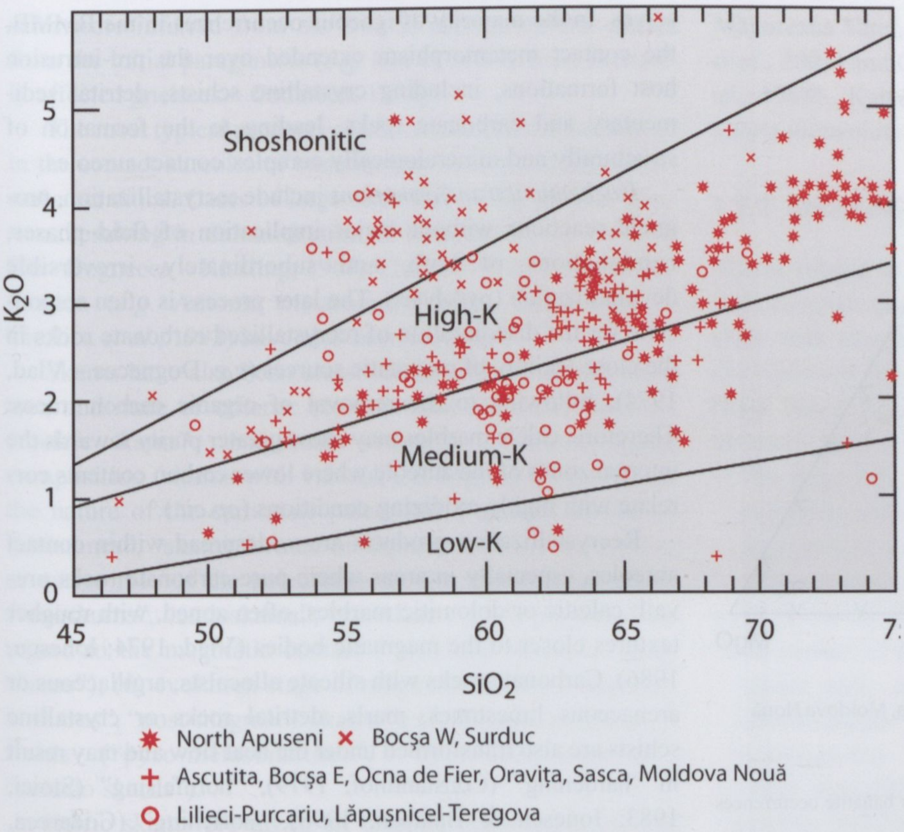


Fig. 8. The SiO_2 *vs.* K_2O diagram (wt%) for various banatite occurrences in Romania (redrawn after Berza *et al.*, 1998).

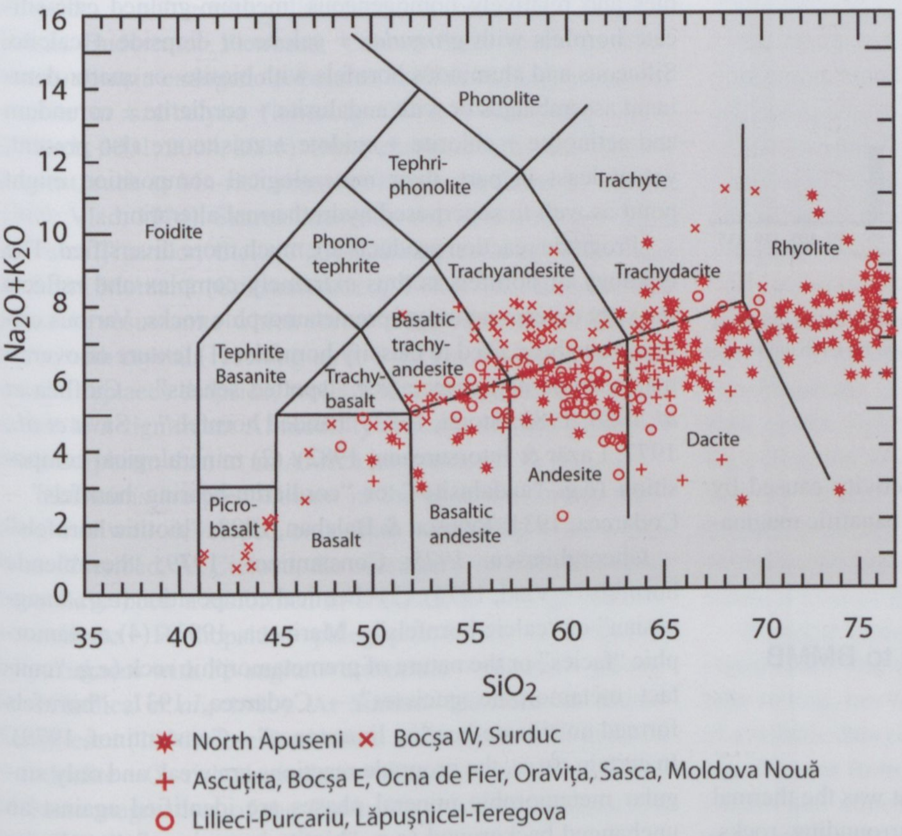


Fig. 9. The SiO_2 *vs.* K_2O + Na_2O diagram (wt%) for various banatite occurrences in Romania (redrawn after Berza *et al.*, 1998).

1.1.5 Geochronology of banatites

A complete compilation of radiometric dating for banatites was published by Ciobanu *et al.* (2002). Banatite ages span between 49.5–77 Ma in Apuseni Mts., 47.2–110 Ma in Poiana Ruscă Mts., 67–89 Ma in Banat, 38–93 Ma in Serbia and 67–94 Ma in Bulgaria, respectively. Maximum of age frequencies occur in the 65-95 Ma interval (Turonian–Maastrichtian) (Fig. 11).

Oldest ages point back to Lower Aptian (*e.g.* Hăuzeşti intrusive; Cioflica *et al.*, 1994). Paleocene-Eocene ages characterize a number of effusive and dyke occurrences in Apuseni Mts., Poiana Ruscă and Timok, whereas intrusives of this age are found in Vlădeasa, Southern Apuseni Mts., Rusca Montană, and in Northern Banat, at Surduc and Bocşa. The largest time span, from Santonian to Eocene was recorded for Glîmboca-Ruschiţa intrusion (Kräutner *et al.*, 1986).

Re-Os ages published by Zimmerman *et al.* (2008) for 50 banatite samples from throughout the BMMB, indicate a much narrower time interval, *i.e.*, 72.2-92.4 Ma, in good agreement with the few previously recorded U-Pb ages and overlapping with median zone of the much more scattered Rb-Sr or K-Ar data. The Re-Os measured by Zimmermann *et al.* (2008) for various segments of the BMMB, distribute as follows: Apuseni Mts. (Băiţa Bihor): 78.7-80.6; Poiana Ruscă (Calova, Valea Căprişoara, Tincova): 72.2-76.6; Banat(Ocna de Fier, Bocşa, Oraviţa, Ciclova, Moldova Nouă): 72.4-82.7; Timok (Majdanpek, Crni Vrh, Veliki Krivelj, Bor): 80.7-87.9; Panagyurishte (Elatsite, Chelopech, Medet, Assarel, Vlaykov Vruh-Elshitsa): 86.8-92.4 Ma. These data suggest as questionable previous evidence for plutonic activity extending beyond the Late Cretaceous (Ciobanu *et al.*, 2002).

Several intermediate, alkali-mafic and lamprophyre dykes from the eastern Apuseni Mts. and eastern Poiana Ruscă are systematically younger than Late Cretaceous, suggesting at least two periods of dyke emplacement, ascribable to two separate magmatic pulses (Ciobanu *et al.*, 2002). The later generation could

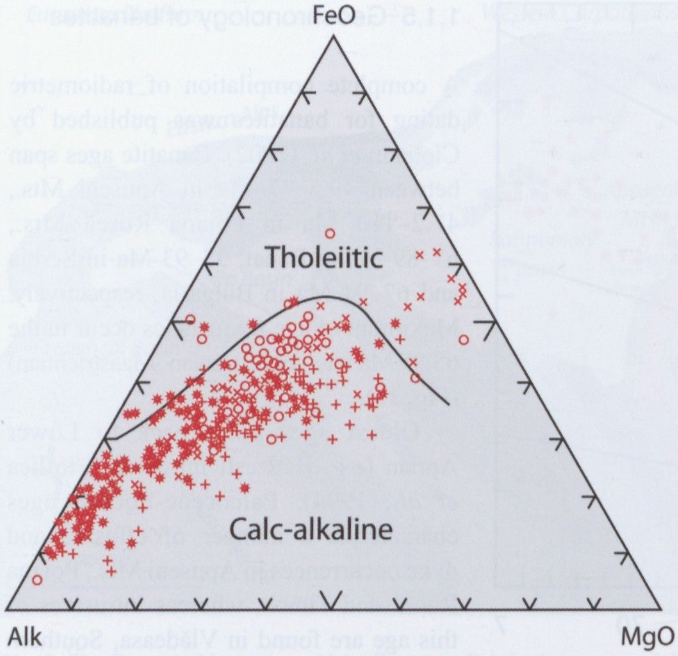


Fig. 10. The Alk-FeO-MgO ternary diagram (wt%) for banatite occurrences in Romania (redrawn after Berza *et al.*, 1998).

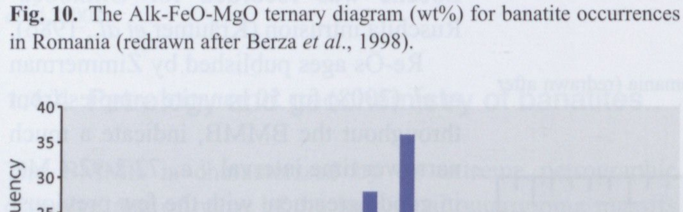


Fig. 11. Frequency histogram of radiometric ages recorded for banatites in Romania, Serbia and Bulgaria (based on data compilation by Ciobanu *et al.*, 2002).

be assigned to re-activation of magmatic activity caused by later tectonics, rather than to a final stage of banatitic magmatism *sensu stricto* (*op. cit.*).

1.2 Contact metamorphism related to BMMB

1.2.1 General features

The main effect of the banatitic emplacement was the thermal and metasomatic transformation of the surrounding rocks. Often, the metasomatic processes had an endomorphous character, affecting to different degrees the intrusive bodies themselves. In the majority of igneous occurrences in the BMMB, the contact metamorphism extended over the pre-intrusion host formations, including crystalline schists, detrital sedimentary and carbonate rocks, leading to the formation of structurally and mineralogically complex contact aureoles.

Isochemical transformations include recrystallization, prograde reactions without major implication of fluid phases, combinations of both, and subordinately, irreversible devolatilization (pyrolysis). The later process is often responsible for the discoloration of recrystallized carbonate rocks in the close vicinity of magmatic sources (*e.g.* Dognecea – Vlad, 1974), following to the removal of organic carbon traces. Therefore, calcic marbles may show greater purity towards the internal zones of the aureole where lower carbon contents correlate with highly oxidizing conditions (*op.cit.*).

Recrystallization products are widespread within contact aureoles, especially in areas where pure carbonate rocks prevail: calcitic or dolomitic marbles, often zoned, with rougher textures closer to the magmatic bodies (Vlad, 1974; Ionescu, 1986). Carbonate rocks with silicate allocalsts, argillaceous or arenaceous limestones, marls, detrital rocks or crystalline schists are also transformed under the heat flow and may result in "hardening" (Constantinof, 1979), "hornfelsing" (Stoici, 1983; Ionescu & Balaban, 1998), "softening" (Codarcea, 1931) or in textural transformations leading to obliteration of initial stratification or schistosity. Recrystallization commonly resulted in micro- or mesoblastic calcic or dolomitic marbles and relatively homogeneous, medium-grained calc-silicate hornfels with *grossular* + calcite or diopside + calcite. Siliceous and aluminous hornfels with biotite- or quartz-dominant assemblages or with andalusite + cordierite ± corundum and actinolite + chlorite + epidote ± zoisite are also present, yet at least in part, their mineralogical composition might point as well to superposed hydrothermal alteration.

Prograde reaction products are much more diversified. The typology of hornfels is thus extremely complex and reflects the very diverse nature of premetamorphic rocks. Various criteria have been used to classify hornfels: (1) texture or overall macroscopic appearance (*e.g.* "spotted schists" – Cioflica *et al.*,1980, 1982; Stoici, 1983; "banded hornfels" – Savu *et al.*, 1977; Lazăr & Întorsureanu, 1982). (2) mineralogical composition (*e.g.* "andalusite-" or "cordierite-bearing hornfels" – Codarcea, 1931; Ionescu & Balaban, 1998; "biotitic hornfels" – Gheorghiţescu, 1975; Constantinof, 1979; "hornblende hornfels" – Vlad, 1974). (3) chemical composition (*e.g.* "magnesian" or "calcic hornfels" – Marincea, 1993). (4) metamorphic "facies" or the nature of premetamorphic rock (*e.g.* "contact metamorphic gneisses" – Codarcea, 1931, "hornfels formed on silicate-bearing limestones" – Constantinof, 1979). In certain cases, the prograde reactions are weak and only singular metamorphic mineral phases are identified against an unchanged background (*e.g.* "biotite in gneisses", "cordierite in porphyritic rocks", "andalusite in biotite-bearing gneisses" – Russo-Săndulescu *et al.*, 1972). Sometimes, the thermal effects are inferred from *the loss* of certain mineral phases from the initial paragenesis (*e.g.* loss of biotite from thermally affected gneisses – Codarcea, 1931).

The most typical products of *allochemical transformations* in the contact aureoles of banatites are skarns and hydrothermal alterations. Cases of large scale Ca ⇔ Mg transfer reactions resulting in dolomitization of limestones (*e.g.* Ocna de Fier–Dognecea – Kissling, 1967; Vlad, 1974) or in dedolomitization (*e.g.* Antoniu metasomatic body, Băiţa Bihor – Cioflica *et al.*, 1992) have also been recorded.

Skarns have also been classified or referred to according to a multitude of criteria: (1) dominant chemical character ("calcic skarns", "magnesian skarns"); (2) mineralogical composition (skarns with various Ca, Mg, Al silicates); (3) the nature of the carbonate paleosome ("skarns formed on limestones", "skarns formed on dolostones"; (4) the passive or active role of the paleosome *vs.* the mineralizing fluids ("exoskarns", "endoskarns", "periskarns"); (5) position with regard to the magmatic contact ("proximal skarns", "distal skarns"); (6) evolution stage of magmatic bodies ("magmatic skarns", "post-magmatic skarns"); (7) thermal character of fluids ("pyro-metasomatites", "hydro-metasomatites", "pseudo skarns").

Calcic skarns prevail in all banatite occurrences located nearby carbonate sedimentary formations. Subordinately, in several massifs from Bihor and Banat, magnesian skarns occur, with assemblages including forsterite + chondrodite + diopside ± phlogopite (clinochlore) + tremolite. At Băiţa Bihor, Budureasa, Pietroasa, Cacova Ierii, Ocna de Fier, skarns contain endogenous borates, such as ludwigite, kotoite, suanite or szaibélyite (Ionescu, 1996a,b; Marincea, 1999, 2000a,b, 2001, 2004, 2006). Other chemical types may also be present, such as Mn-rich skarns at Dognecea (Vlad & Vasiliu, 1969; Vlad, 1974). Skarns unusually rich in aluminium occur in Valea Ţiganilor, Ciclova (Constantinescu *et al.*, 1988) and at Sasca Montană (Constantinescu, 1970). The main Al-rich phase is vesuvianite which forms monomineralic concentrations, with crystals reaching up to 5-10 cm. Commonly, vesuvianite replaces diopside, wollastonite and garnet and points rather to a significant Al-mobility towards the late phases of metamorphism than to an Al-rich host rock.

Exoskarns are predominant in the banatitic contact aureoles, but well developed endoskarn assemblages have also been described. At Ciclova, the outer parts of a monzodiorite body have been transformed in endoskarns with grossular + vesuvianite + Fe-diopside + phlogopite, locally accompanied by periskarns with Fe-augite + orthoclase + titanite + grossular (Cioflica *et al.*, 1980). At Surduc, Marincea & Russo-Săndulescu (1996) described calcic endoskarns with prehnite + andradite + Ca-rich plagioclase + diopside, formed on bodies of basic magmatites of the Coniacian – Maastrichtian cycle (see Table 1).

High-temperature skarn assemblages with spurrite-tilleyite-gehlenite, or diopside-gehlenite occur at Cornet Hill-Măgureaua Vaţei, Apuseni Mts. (Marincea *et al.*, 2001, Pascal *et al.*, 2001) and Ogaşul Crişenilor-Oraviţa (Constantinescu *et al.*, 1988b, Katona *et al.*, 2003) where they are related to quartz monzonite-monzodiorites, or diorite-gabbros.

1.2.2 Structural typology and regional distribution

Skarns related to BMMB in Romanian have been examined and classified also with respect to regional structural relationships with surrounding rocks. Three main types, have been distinguished (Cioflica & Vlad, 1973; Vlad, 1997), (1) the Băiţa Bihor type, (2) the Ocna de Fier type and (3) the Moldova Nouă type. (Fig. 12).

- The *Băiţa Bihor type* skarns (Fig. 12.A) may develop along magmatic-sedimentary contacts, but more often they form distal bodies along fractures or thrust planes, or highly brecciated metasomatic columns.
- The *Ocna de Fier type* skarns (Fig. 12.B) are controlled by the contact of the Ocna de Fier–Dognecea pluton with carbonate rocks and form discontinuous bands, irregular- or tabular-shaped bodies and metasomatic veins. A relatively homogeneous carbonate paleosome favoured diffusion, rather than infiltrative exchange as the major metasomatic process involved. Metasomatic asymmetrical zoning is obvious: an inner zone with andradite-dominant assemblages, locally rimmed by wollastonitites and an outer zone with pyroxenic skarns — diopside at Ocna de Fier and Mn-hedenbergite at Dognecea (Vlad, 1974).
- The *Moldova Nouă type* skarns (Fig. 12.C and D) develop at Moldova Nouă, Sasca Montană and partially at Oraviţa-Ciclova, where they are controlled mainly by contact zones between subvolcanic bodies and carbonate rocks. They occur commonly as lenses with branching apophyses in the vicinity of igneous apices. Skarns of this type display no striking mineral zoning, but some authors (Gheorghiţescu, 1975) described crypto-zonings within the garnet skarns due to the increase of andradite contents towards the carbonate rocks.

Peculiar morphological aspects deviating from these schemes are ubiquitous, however. At Oraviţa, in Ogaşul Rândunicii zone, garnet-meionite skarns occur as veins or sigmoidal bodies within the crystalline schists of Bocşiţa-Drimoxa formation (*e.g.* Iancu, 1986). In Coşoviţa Hill (Oraviţa), where no contact zones of a large igneous body is obvious, skarns form a continuous band between Jurassic limestones and the crystalline schists of the Caraş group.

Regional zoning of magmatic occurrences with their associated skarn and ore deposits in Banat, in terms of Andean-type setting, has been examined by Vlad (1997). Refinement of available data concerning exoskarn host rock and local zoning, distance from productive intrusion, skarn type, skarn formation and mineralogical composition points to three main units which will be summarized as follows.

A. *The Marginal unit* (Moldova Nouă-Sasca Montană) contains distal (around apophyses of the intrusion) dark skarns

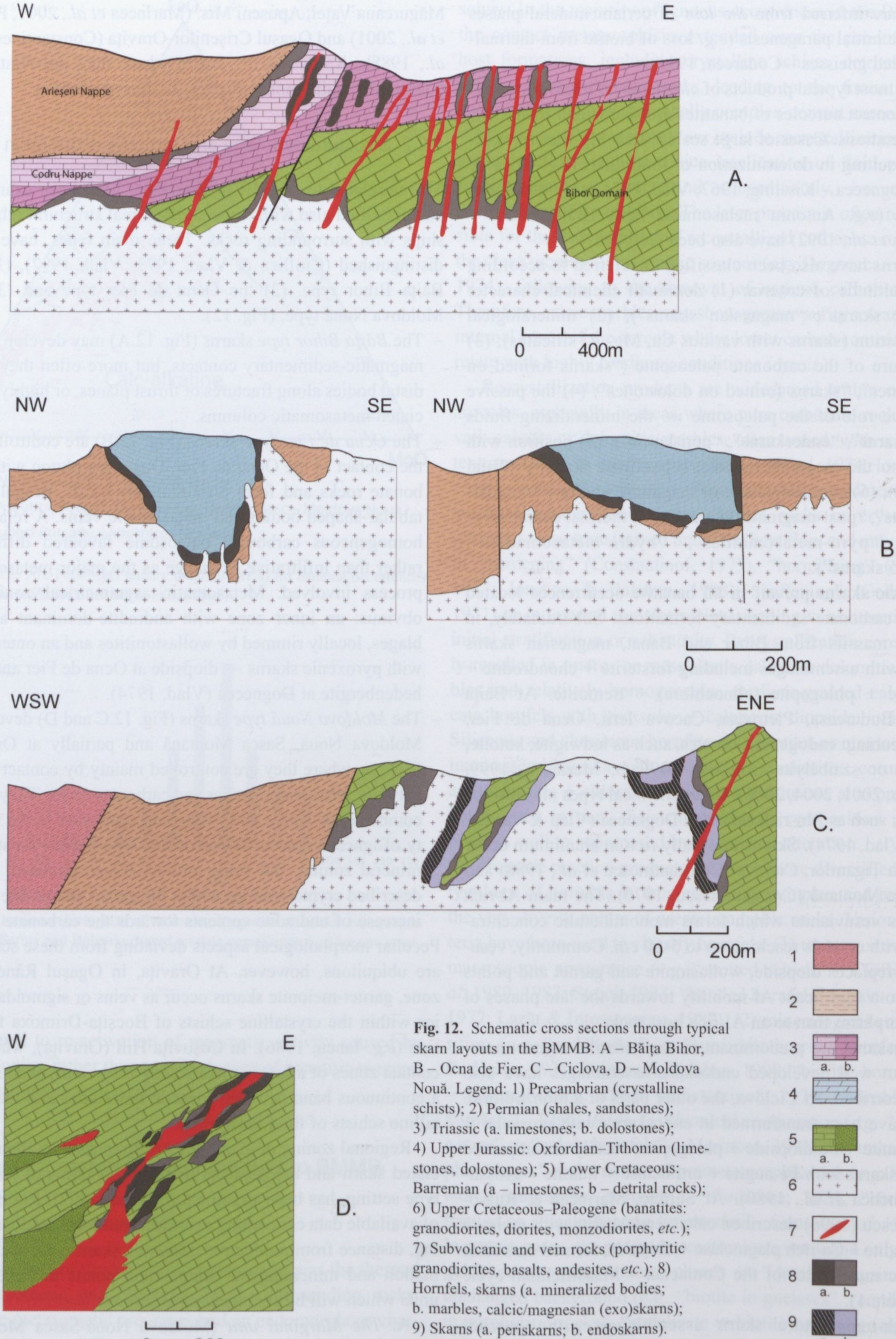


Fig. 12. Schematic cross sections through typical skarn layouts in the BMMB: A – Băiţa Bihor, B – Ocna de Fier, C – Ciclova, D – Moldova Nouă. Legend: 1) Precambrian (crystalline schists); 2) Permian (shales, sandstones); 3) Triassic (a. limestones; b. dolostones); 4) Upper Jurassic: Oxfordian–Tithonian (limestones, dolostones); 5) Lower Cretaceous: Barremian (a – limestones; b – detrital rocks); 6) Upper Cretaceous–Paleogene (banatites: granodiorites, diorites, monzodiorites, *etc.*); 7) Subvolcanic and vein rocks (porphyritic granodiorites, basalts, andesites, *etc.*); 8) Hornfels, skarns (a. mineralized bodies; b. marbles, calcic/magnesian (exo)skarns); 9) Skarns (a. periskarns; b. endoskarns). (Redrawn and modified after Vlad, 1997).

with grandite and subordinately vesuvianite, Fe-diopside, wollastonite and scapolite. Garnet *vs.* pyroxene ratio is about 10/1. Exoskarn host rock is commonly limestone marble and its zoning is not well expressed. However, the sequence grandite$_{75-85and}$ – Fe-diopside ± wollastonite – marble may be considered as characteristic. Skarn formation was monoascendant under relatively oxidizing/alkaline conditions.

B. *The Median (Intermediate) unit* (Oravița-Ciclova) contains both proximal (around plutons) and distal (along lithologic discontinuities and/or fractures in intruded rocks) skarns with lower values of garnet *vs.* pyroxene ratio (5/1 in proximal skarns to 3/1 in distal skarns). Skarns formation was polyascendant in an oxidizing/alkaline regime. Zoning is well expressed at least for the proximal skarns: grandite$_{65and}$ – Fe-diopside ± wollastonite – marble. Distal skarns display a superposed zoning: a) diopside – grandite$_{45and}$ ± vesuvianite ± diopside – grandite$_{50and}$ – grandite$_{76and}$ – marble (in the skarns located at the contact between hornfels and marbles); b) diopside – grandite$_{39-43and}$ – diopside – scapolite + diopside – diopside – diopside + scapolite (in metasomatic veins located in hornfels). Exoskarn host rocks are either limestone marbles or recrystallized carbonate-pelite sequences.

C. *The Inner unit* (Dognecea–Ocna de Fier) display proximal (around plutons) and distal (at the contact between crystalline schists and marbles) skarns with grandite + diopside – hedenbergite – johannsenite + wollastonite + manganilvaite. Garnet *vs.* pyroxene ratio ranges from 3/1 in proximal skarns to 1/5 in distal skarns. Skarn formation was monoascendant under relatively oxidizing/alkaline conditions for proximal skarns and reducing/acid for the distal ones. Zoning is particularly well expressed: a) grandite$_{83-89and}$ – manganoan Fe-diopside – marble (for proximal skarns); b) grandite$_{80-94and}$ – manganoan Fe-diopside – Mn-hedenbergite to Fe-johannsenite – manganilvaite (wollastonite) – marble (for distal skarns).

1.2.3 Hydrothermal alteration

A continuum between skarns and hydrothermal alterations is specific to all skarns occurrences in the BMMB, but the effects of hydro-metasomatism are usually extended beyond the limits of skarn zones.

Hydrothermal retrograde reactions affecting garnets and vesuvianite, commonly result in epidote + chlorite ± carbonates, quartz whereas pyroxenes breakdown to form tremolite–actinolite + serpentine + talc. High temperature hydrothermal assemblages with tourmaline + quartz ± orthoclase, magnetite were described in relation to porphyritic granodiorite intrusions from Oravița (Popescu & Constantinescu, 1977; Constantinescu *et al.*, 1988a) and from Sasca Montană (Constantinescu, 1980).

More abundant are the hydrothermal assemblages containing a) K-feldspar + biotite ± quartz, muscovite (potassic alteration), b) epidote + actinolite + chlorite + quartz + calcite (propylitic alteration), and c) illite + quartz ± chlorite, calcite, pyrite (phyllic alteration) which are frequently related to ore deposits. Rich epithermal alteration with zeolites (laumontite, stilbite, thomsonite, chabazite *etc.*), gypsum, anhydrite, and crypto-crystalline silica are also present.

1.3 Metallogeny of BMMB

The studies of Cotta (1864) upon the Fe-Cu-Pb-Zn skarn deposits of Dognecea, Ocna de Fier and other mines in Banat are the first widely cited papers to define a class of "contact-deposits" found at the contact of igneous intrusions of banatites and limestones where "garnet-rock" is found (Burt, 1982). Since then, more than 50 mineral deposits have been discovered, and pending of a given historical epoch, they were of some economic interest. The mineralization related to the BMMB is represented mainly by porphyry copper, massive sulphide, skarn and vein (epithermal and mesothermal) deposits (Berza *et al.*, 1998).

By 1994, the ore deposits related to the BMMB accounted for approximately 20% of the total metal resources of Romania (Vlad & Borcoș, 1994), but today, only the porphyry copper ore deposit at Suvorov (Moldova Nouă) and very few skarn deposits are still in production. Mineralization is almost exclusively associated with banatites belonging to Stage 3 (Paleocene – Cioflica *et al.*, 1992), to Cycle II – Upper Danian-Lower Ypresian (Ștefan *et al.*, 1988) or to the Maastrichtian-Paleogene B.I and B.II cycles (Russo-Săndulescu, 1993) (Table 1).

1.3.1 Types of mineral deposits in the BMMB

Copper metallogeny is predominant and distinguishes the BMMB in the context of the larger ABCD belt (Ciobanu *et al.*, 2002). Copper ores are commonly associated with Pb-Zn, Au-Ag, and subordinately with Mo, Bi, W, Fe, Co, Ni and B. Mineral deposits within the BMMB are strongly differentiated with respect to host rock types and depth of magma emplacement. Shallower hypabyssal bodies are hosts for porphyry copper ores with Cu ± Au, Ag, Mo: *e.g.* Moldova Nouă (Gheorghițescu, 1972; Gheorghiță, 1975), Majdanpek, Cerovo, Veliki Krivelj, Bor (Timok Massif, Serbia – Janković, 1990), Elatsite, Chelopech, Assarel (Panagyurishte district, Bulgaria – Strashimirov *et al.*, 2002). High-sulphidation epithermal deposits are sometimes spatially associated with larger porphyry copper systems (*e.g.* at Bor and Majdanpek – Ciobanu *et al.*, 2002). Subeconomic porphyry copper (± Mo) accumulations are also present at Oravița, but hydrothermal alteration is far less pervasive than at Moldova Nouă. Decimetric size fissures in granodiorites – often smeared with chalcopyirite and molybdenite, delimitate granodiorite blocks almost unaffected by alteration. Large shallow porphyry-style systems with pyrite halos (and/or skarn halos) extend only south of Poiana Ruscă but they lack economic mineralization:

e.g. Tincova-Ruschiţa, Şopot-Teregova-Lăpuşnicel areas (Vlad, 1997; Ciobanu *et al.*, 2002 and references therein; Zimmermann *et al.*, 2008).

Copper and base metal skarn deposits form the most widespread metal accumulations across the BMMB (Table 2). Some occurrences are set apart by prominent Fe metallogeny (*e.g.*, Ocna de Fier – Nicolescu & Cornell, 1999; Cook & Ciobanu, 2001; Maşca Băişoara – Lazăr & Întorsureanu, 1979). Ocna de Fier is considered typical for fluid plume mineralization in a proximal skarn setting. Forsterite skarns host a magnetite – chalcopyrite – bornite mineralization, which represents the inner Cu-Fe core of the deposit (Cook & Ciobanu, 2001). Scheelite forms significant concentrations in the Cu-Mo mineralization of Băiţa Bihor (*e.g.* Cioflica *et al.*, 1992) and Oraviţa (*e.g.* Constantinescu *et al.*, 1988a). Bismuth sulphosalts are minor but ubiquitous components of many skarn deposits. Extremely rich and diverse assemblages have been described at Băiţa Bihor (*e.g.* Žak *et al.*, 1994; Cioflica *et al.*, 1995; Topa *et al.*, 2003), Valea Seacă (*e.g.* Ilinca, 1998, 2006; Ilinca & Makovicky, 1999), Ocna de Fier (*e.g.* Ciobanu & Cook, 2000), Oraviţa-Ciclova (*e.g.* Popescu & Constantinescu, 1977; Ilinca, 1998).

Regional zoning of skarn deposits in correlation with Upper Cretaceous subduction settings was described by Cioflica *et al.* (1992), Vlad (1997) and by Berza *et al.* (1998). The later authors distinguished two major metallogenic segments within the BMMB (Apuseni Mts. and Southern Carpathians), each one still amenable of division into further units (sub-belts, zones and districts). Local zoning is well expressed for numerous ore environments in the BMMB. At Băiţa Bihor (*e.g.* Cioflica *et al.*, 1977; Berza *et al.*, 1998) the areas closest to the magmatic sources are enriched in molybdenite. Towards the external zones, Mo-rich ores grade into Mo-W-Bi-Te (in calcic skarns) or Cu-W-Bi (in magnesian skarns), Pb-Zn (in magnesian skarns and sedimentary schists) and finally into boron mineralization overlapping dedolomitization zones. At Dognecea–Ocna de Fier, Ciobanu & Cook (2000) described a Cu-Fe → Fe → Pb-Zn metal zoning around a single granodiorite core in the deepest part of the deposit.

1.3.2 Paragenetic features

The polyascendant character of skarn deposits in the BMMB has either been asserted (*e.g.* Popescu & Constantinescu, 1977; Cioflica & Vlad, 1981) or argued against (Ilinca, 1998). Extensive sampling and detailed investigation of ore paragenesis over numerous skarn deposits in the BMMB, plead for coeval and isochronous mineralization, most probably formed from the differentiation of a single fluid. Moreover, apart from several cases of prominent metallogeny (*e.g.* Fe at Ocna de Fier), the overall paragenetic sequence for virtually all mineral deposits in the BMMB is roughly the same, both as mineral phases and deposition sequence. Ilinca (1998) separated the following ore deposition sequences:

– Stage 1 (“siderophile” – Fe ± Co, Ni, As, Mn) – iron oxides and sulphides, Co, Ni, Fe arsenides and sulpharsenides, with subordinate Fe-Mn calcic silicates. The stage signifies the highest deposition temperatures and a continuous decrease of oxygen fugacity (*e.g.* hematite → magnetite, magnesioferrite) *vs.* increase of sulphur fugacity (pyrrhotite → pyirite). At Băiţa Bihor, Ocna de Fier, Oraviţa, Ciclova and Sasca Montană early iron sulphides are accompanied by nickeline, rammelsbergite, cobaltite, gersdorffite (Ilinca, 1998), Co-pentlandite (Cook & Ciobanu, 2001), linnaeite, bravoite, siegenite, millerite (Constantinescu, 1980).

– Stage 2 (Pb,Zn ± Ag, Bi, Fe) – forms the bulk of the mineralization in numerous occurrences across the BMMB. The stage is represented by galena (with up to 10 mol% matildite) and sphalerite usually with 14-15 mol% FeS). Invariably, the direct contact between galena and siderophiles, shows the late character of the Pb-Zn phases.

– Stage 3 (Pb, Bi ± Ag, Sb, Te, Cu) – contains Pb-(Ag)/Bi sulphosalts (lillianite homologues (heyrovskýite, lillianite, vikingite), cosalite, cannizzarite, galenobismutite. Some Pb-Bi sulphosalts are formed on older galena, most probably belonging to the previous stage. Stage 3 members often substitute siderophile sulphides likely to belong to stage 1. The same stage witnesses the deposition of Bi (±Pb) tellurides: joseite A-B, “protojoseite”, and rarely native bismuth. Cosalite represents a late deposition within this stage. It contains small amounts of Cu and replaces heyrovskýite, lillianite and cannizzarite. In Sasca Montană and Moldova Nouă, stage 3 assemblages are mostly represented by Sb (±As) sulphosalts: geocronite, boulangerite and zinkenite, often formed on older galena.

– Stage 4 (“copper metasomatosis” (CM) – Cu, Bi ± Pb, Ag, Fe, Sb, Te, As, Zn, Au, Mo, W) – is distinguished by progressive increase of Cu content in sulphides and sulphosalts. Massive deposition of chalcopyrite, cubanite and bornite takes place in this stage. Fahlore minerals (tetrahedrite–tennantite, enargite, luzonite) occur also in this stage, most frequently on Fe, Zn, Sb, As phases of earlier stages. Chalcopyrite takes the form of massive monomineralic precipitates, with conspicuous growth zoning. At Băiţa Bihor, Oraviţa and Ciclova, chalcopyirite and cubanite are often pseudomorphs after pyrite and replace Co and Fe sulpharsenides. “Chalcopyrite disease” phenomena, *i.e.* chalcopyrite (± bornite, mackinawite) blebs in sphalerite (Barton & Bethke, 1987; Bente & Doering, 1993) are widespread and represent yet another facet of CM. Bi sulphosalts are particularly sensitive to CM transformations. First Bi phases show an increased Bi_2S_3/PbS ratio compared to previous stages and grade towards decreasing Bi/Cu. Such minerals form directly or by replacing older Pb-Bi sulphosalts (especially cannizzarite and galenobismutite): proudite, lillianite (with up to 2.9 at% Cu), felbertalite, (high-Cu) cosalite, neyite, junoite. The sequence continues with nuffieldite and massive deposition of bismuthinite derivatives, covering the entire range

Table 2. *Features of selected skarn deposits in the Romanian portion of BMMB (modified after Ciobanu et al., 2002) mgt – magnetite, py – pyrite, po – pyrrhotite, cpy – chalcopyirite, bn – bornite, mob – molybdenite, sph – sphalerite, gn – galena, sch – scheelite, hem – hematite, Biss – bismuth sulphosalts*

Region	Deposit	Skarn type	Sedimentary	Magmatic	Ore morphology	Skarn mineralogy	Ore mineralogy
Apuseni Mts.	Băişoara	Fe Zn-Pb	Pre-Mesozoic limestones, dolostones	Granodiorite	Irregular bodies, along contact Lenses in schists, distal to Băişoara	garnet, diopside, epidote forsterite (serpentine), ludwigite	mgt, py, po, mob sph, gn, py
	Băiţa Bihor	Cu (Mo, W, Bi) (Zn-Pb)	Triassic/ Cretaceous limestone/ dolostone	Deep granite granodiorite pluton dykes	Irregular bodies along Blidar and Secundar contacts, Metasomatic stockwork columns (Antoniu, Baia Roşie)	garnet, diopside, wollastonite, forsterite (serpentine), ludwigite, chondrodite, clinohumite, szaibélyite	cpy, bn, mol, sph, gn, sch, Biss
	Valea Seacă	Cu (Pb-Zn, Bi)	Upper Cretaceous limestones	Granodiorite	Along magmatic contacts, small stockworks	garnet, diopside	cpy, mgt, mob, Biss
Poiana Ruscă Mts.	Ruschiţa, Tincova, Ascuţita	Zn-Pb-(Fe)	Pre-Mesozoic limestones	Granodiorite diorite	Lenses in crystalline schists, Irregular bodies	epidote	sph, gn, hem
Banat	Ocna de Fier Dognecea	Fe-(Cu,Bi) Zn-Pb	Upper Jurassic – Lower Cretaceous dolostones	Granodiorite	Irregular bodies along dolostones/schist contact Distal stockworks, irregular bodies	garnet, diopside hedenbergite, tremolite, wollastonite, forsterite (serpentine), ludwigite	mgt, hem, bn, cpy sph, gn. hem, py, mob
	Oraviţa-Ciclova	Cu (Mo, W, Bi)	Palaeozoic pelites, Upper Jurassic – Lower Cretaceous carbonate sedimentary	Granodiorite, monzodiorite, diorite, gabbro	Sparse porphyry-style Stockworks, lenses along contacts and within limestones	garnet, diopside, vesuvianite, gehlenite	cpy, po, py, mob, sch, Biss
	Sasca Montană	Cu (Mo)	Lower Cretaceous carbonate sediments	Granodiorite, monzodiorite, diorite	Lenses along magmatic contacts Sparse porphyry features	garnet, diopside, vesuvianite	cpy, po, py, mob
Moldova Nouă	Cu		Jurassic – Cretaceous carbonate sedimentary	Porphyritic granodiorite	Irregular bodies along magmatic contact	garnet, diopside	cpy, py, mgt, py

between bismuthinite and aikinite. In antimony dominated assemblages, bournonite is formed. The highest Cu contents are embodied by makovickyite-cupromakovickyite, paděraite, hodrushite and kupčíkite and finally by pure Cu-Bi sulphosalts such as emplectite and wittichenite. At Băiţa Bihor, Oraviţa and Ciclova, the CM stage includes electrum (10-15% Ag), scheelite and molybdenite. A synoptical view of the overall paragenetic sequence is given in Fig. 13.

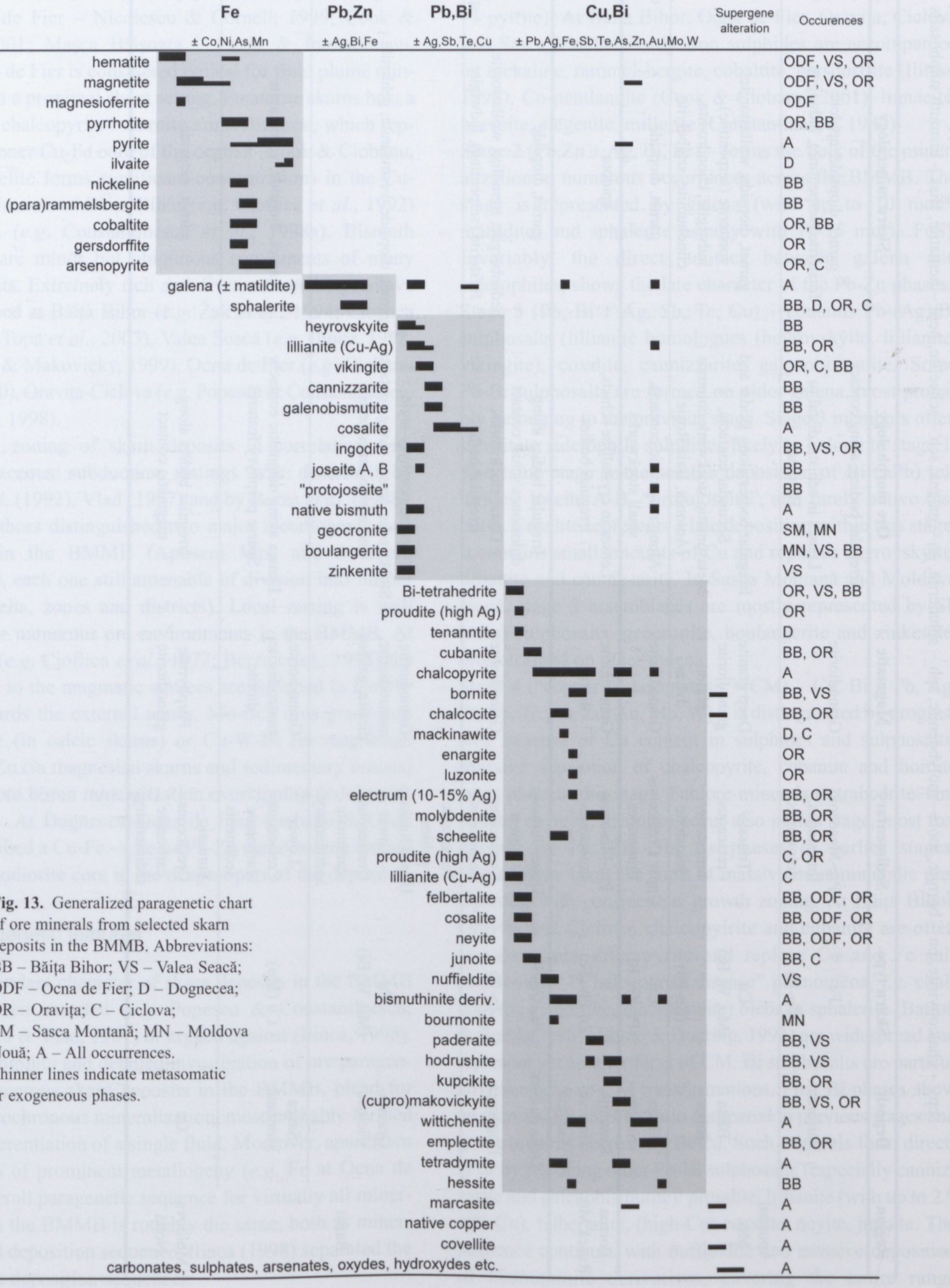


Fig. 13. Generalized paragenetic chart of ore minerals from selected skarn deposits in the BMMB. Abbreviations: BB – Băiţa Bihor; VS – Valea Seacă; ODF – Ocna de Fier; D – Dognecea; OR – Oraviţa; C – Ciclova; SM – Sasca Montană; MN – Moldova Nouă; A – All occurrences. Thinner lines indicate metasomatic or exogeneous phases.

1.3.3 Brief history of mining in the BMMB

The mining history throughout the BMMB has developed unevenly. Ancient populations in the Apuseni Mountains have been focusing upon the richer and more accessible gold and base-metal deposits related to Neogene volcanism. Instead, in Banat area, skarn deposits have been exclusive sources for metallic raw materials and the emancipation of mining relied entirely on Late Cretaceous-Paleocene banatitic mineral environments.

It is likely however, that skarn deposits in Northern Apuseni, especially those in Crişul Negru Basin, have been subjected to mining and metal working ever since the Dacian times. In 1270, King Stephen V granted bishop Monoslov of the Roman-Catholic Diocese in Oradea the right to carry out mining activities in Băiţa Mts. (Degău, 2007). An epoch of economic growth commenced, as suggested by the newly constructed fortress of Finiş and by the city of Beiuş becoming the second city of residence for the major landowner in the area: the Roman-Catholic Diocese of Oradea. Numerous mining experts and workers were brought Germany, France, Austria and from the northern parts of Hungary, and the first large-scale operations started for gold, silver and copper at Băiţa and for iron at Vaşcău. Local population adopted rapidly the new crafts and started to practice gold panning from alluvia and, iron/copper metal working. Virtually every settlement had at least two or three blacksmiths supplying a whole diversity of metal products for domestic and military use. Copper mining became increasingly important and by mid-16th century a whole new locality – Rézbánya – took its name from its main industrial activity and mineral resource. The benefits of the local society were undoubtedly great, if we only think about the volume of ore mined. Historical statistics show that by the end of the 19th century, Băiţa mine provided 1567 kg of silver worth 14,106 florins, 5326 kilograms of lead worth 878 florins and 7399 kg of copper worth 4899 florins. Mining of iron developed continuously at Vaşcău and Pietroasa, reaching a quantity of 1500 centners (approx. 75,000 kg) in 1839.

In the late 1940s, the Soviets started a massive mining operation for uranium at Avram Iancu, nearby Băiţa Bihor. Mining personal grew to over 20,000, but the military in charge with keeping the mine under control, kept the pace at over 10,000 people. Two new cities emerged in 1952, within 15 km from the mine: Petru Groza (today Ştei) and Nucet. Over 300,000 tons of high-grade uranium ore have been transported to the Soviet Union.

Marble deposits from recrystallized limestone environments were heavily exploited at Vaşcău, Pietroasa, Budureasa, Coleşti and Chişcău. Much of this material was used for administrative and residential buildings in Oradea and Budapest.

The early days of mining in Banat area share a much more complex story. The oldest relics of human activity in Banat region date from 1900–1700 BC, *i.e.*, from the transition phase between the New Stone Age and the Bronze Age. Pottery decorated with incised or relief markings, flint blades and axes, and hammered copper awls were found in a nomadic shepherd settlement at Colţan near Ocna de Fier. Mining during this period may not have been anything else but picking the native copper from natural outcrops, yet the smooth shaped tools show careful craftsmanship and speak about a rather prosperous society.

The Bronze Age (about 1800–1200 BC) saw the introduction of an occupation that was to have vital importance to the region thereafter: namely, agriculture. However, copper mining and processing continued as proved by the archaeological finds at Bocşa, Ocna de Fier, Dognecea and Oraviţa. Near the Iuliana quarry in Ocna de Fier, scanty remains of a foundry dating from this period and few of its products: sickles and bronze bracelets, were also found. The transition to the Iron Age seems to have been beset without difficulties, at least not of a technical nature if only the plentiful iron ores occurring near the surface in the Ocna de Fier region are to be considered. As a matter of fact, the numerous Iron Age slag fields found near Bocşa Montană show an intensely sustained iron processing activity.

The existence of Roman mining within the boundaries of south-western Banat has not been in doubt for at least two hundred years. The 18th century scholar and explorer Francesco Griselini (1780) mentioned the existence of a Roman funeral plaque found near some mining wells at Moldova Nouă, most probably testifying to the Roman concern for the copper ores in the area. Indeed, after the war in 106 AD, when Emperor Trajan conquered Dacia, the Roman's interest was principally cantered on the mining of the renowned gold and other metal resources which were close at hand in the central part of the province. A votive plaque found near Zlatna (the former *Ampelum*) is interpreted by modern historians as a solemn oath to the gods for the success of the action: IOV. INVENTORI/ DITI. PATRI TERRAE MATRI/DETECTIS DACIAE THESAVRIS/DIVVS NERVA TRAIANVS/CAES. AUG./VOTUM SOLVIT.

Consequently, a *Collegium Aurarium* was settled in *Ampelum*, which was mainly intended to set technical and financial control over the gold and base metal operation. With an appointed *procurator aurarium* chosen from Trajan's former slaves, the *Collegium* managed to organize the ores extraction not only within *Dacia mediterranea* (today's Transylvania) but to expand its activity in *Dacia ripensis* (Banat), too. Here, they dealt mainly with copper ores, but gold, even in minor amounts, was not left apart. Traces of Roman mining were still visible until not so long ago at Cracul de Aur (in Ocna de Fier) where several small galleries and miner's rushlights were discovered. Nearby, at Berzovia (the former *Berzovis*), historical sources mention a celebrated *Schola fabrorum*, within which basic skills of metal processing were acquired.

Little is known about the post-Roman period, but for the later middle ages we have the assistance of some records surviving from 1552, which describe the intensive exploitations of gold in the so-called *Wolfganger Gebirge* and *Reicher Spitz* areas near Ocna de Fier–Dognecea zone. Following the battle of Mohács in 1524, the 164 years during which Banat was a Turkish *pashalik*, witnessed only little or no progress at all in the ore extraction field. Facing a permanent state of war and showing scarce interest in economic development of the occupied territory, the Turks exerted practically no influence in the matter so that the ore pits supplied mainly the raw material for the domestic needs of the natives. Few iron slags and furnaces dating from this period, were found in the vicinity of Moravița Valley and in the Dealovăț Hill in Ocna de Fier. Austrian documents from the second half of the 1700s speak about the *Johanni* mine in Ocna de Fier which was exploited by the Turks and reopened in 1720 with the assistance of local miners, who worked there during the occupation, for copper, lead and silver. However, judged by the appearances of the mine, it seemed that the works were older than the Turkish occupation testifying to a constant and sustained autochthonous activity. Even the very old toponym "Bocșa" (a locality near Ocna de Fier) originating in the term *bocșani* – charcoal makers – suggests a permanent need of partly burned wood for metal processing.

After the peace treaty of Passarowitz in 1718, Banat came under Austrian rule, which put the province on the threshold of a period of extraordinary expansion. The prime task now was to restore the mining industry; an aim which was largely completed by about 1720 under Charles VI, who organized four *Mountainous Offices* in Dognecea, Oravița, Sasca and Moldova, in order to cover the major productive areas. Yet, the availability of skilled miners was scarce among local inhabitants essentially engaged in agricultural production, and the newly established mining school in Oravița produced mainly executive staff unable to meet the demand for people effectively working in the mines. Such were the circumstances that induced Emperor Charles VI to enact major privileges for the miners in Banat and to grant "all the possible exemptions from taxation" if someone was to get willingly engaged in mining work. These measures were intended to attract people from the neighbouring provinces, but unfortunately, they didn't resulted immediately in providing the desired source of operatives, since many newcomers from Carinthia, Styria and Tyrol were mining experts, engineers or civil servants.

Nevertheless, the ore extraction begun to acquire industrial characteristics and the south-western part of Banat witnessed a period of phenomenal development which established the territory of the four *Mountainous Offices* almost as a rival to Timișoara (the capital of Banat) in the determination of fiscal policy. It depended a good deal on improved communications and on heavy and continual capital investment. New metal processing centres were established in Bocșa, Dognecea and Oravița. The outputs were chiefly iron, copper and lead, and some of the ores were send to Annaberg for the extraction of silver. The metals were heavily exported to Constantinople, Venice, Trieste, Poland, Latvia *etc.* Again, mine operatives were insufficient, but soon, a major immigration from Oltenia and Muntenia has started, bringing thousands of people to work in the mines or foundries and providing a readily available, yet unstable source of workers. "As soon as they earn 50-100 florins, and it is quite easily to make this money in a very short time, many *bufeni* (immigrants coming from Oltenia) fled the province, and thus, a great deal of money is lost for the country", wrote Ehrler (1774) in a discussion upon the utility of using foreign workers inside the Empire. According to Ehrler, by that time, Banat produced about 280 tons of copper, 1680 tons of iron and 170 kg of silver per annum "…and things would be even better if an increased number of subjects would acquire the skills necessary in ore extraction".

Old documents mention that gold was extracted, too; several mines were opened for gold at Bocșa, Lescovița-Zlatița, Oravița and Sasca, but seemingly, they have been unproductive. Local authorities were equally concerned with alluvial gold deposits connected with Caraș, Nera and Bârzava rivers, which were regularly exploited in those days by groups of nomadic gypsies, but they failed in their attempt to expand this occupation with advantage. Gold indications described by the gypsies were elusive; production was low and unstable, largely depending on rainfall *etc.* Still, the main goal of mining industry in Banat was copper. Mining plans and sketches available in Romanian archives display hundreds of copper mines in a puzzling pattern of galleries and wells. One of them, the mine *Simon und Juda* in Ocna de Fier, was described by Ignaz von Born (1774) as being the richest in Europe: "...all its galleries go in pure copper ore with no sterile, whatsoever". There was in the middle of a new and lasting period of economic progress. Some idea of the expansion of mining industry in south-western Banat may be gauged from the fact that the currencies supplied from the Empire were quite insufficient for the local needs so that a mint has to be established in Ciclova (a suburb of Oravița at the time) where copper coins with a distinctive "O" – for Oravița, were issued. A former village with only 77 houses recorded by an official census in 1717, Oravița became the economic and financial capital of Banat and the first town within the present borders of Romania to enjoy some technical and cultural achievements such as theatres and railroads (Fig. 14).

Mineralogical and geological descriptions of Banat had already begun to appear. It is entirely to the credit of pioneers like Born, Griselini or Ehrler that the information they put on record tell more about the mineralogical richness of this territory than one can see today. Though somehow naive (for example, Griselini failed to notice the presence of magmatic rocks connected with ores), their studies attempted not only to give a comprehensive inventory of minerals and rocks, but to explain the genesis of the ore deposits, too. Mentions such as *Crystallis spatosa acaulis*, *crystallis pyramidalibus trinquetris*, *Cuprum vitratum*, *violaceum et caeruleum aut rubrum*, *Granati martialis crystallisatus dodecaedrus obscuroflavus et*

Fig. 14. The Oravița-Anina railroad is the second mountain railroad ever built in Europe. It was intended to connect the coal deposit in Anina with the Danube ports. Construction took place between 1860 and 1863; the railroad measures 33 km, with 10 viaducts and 14 tunnels, and remains one of the most scenic routes in Romania (Photo: Detlef Schikorr – www.drehscheibe-foren.de).

nigrescens, *Asbestus fibris durioribus parallelis, cum granato martialis* or *Mica martialis drusica, squamis concentratis* are perhaps the first mineralogical descriptions ever made here. Noteworthy are the later works of Bernhard von Cotta (1864) who was the first to describe the Alpine intrusive rocks in Banat, which he called *banatites*, and to recognize their consanguinity.

A new conflict with the Turks in 1837 brought the mining industry of Banat to a standstill and its inhabitants were further impoverished by war taxation. An outbreak of plague in 1840 added to their miseries. Many officials and colonists fled the province and the mining directories have ceased to function. Thereafter, the activity resumed, the *Offices* were re-established, but much apathy became apparent due to the post-war economic crisis and the central authorities from Vienna could no longer manage the mines directly. Thus, the mining fields were leased to individuals *(Allgewerkschaft)* or to co-operative societies *(Grubengewerkschaft)* which eventually became independent under the form of a so-called "free and self-supporting exploitation".

After the social and political movements of 1848, owing to persistent financial crisis, the Austrian authorities have decided to license some forests, railroads and mines. As a result, the *Kaiserliche und Königliche Privilegirte Staatseisenbahngesellschaft* (STEG) was founded in 1855; a powerful organization, which ignored the traditional co-operative system of the leaseholders and even their right to possess mining fields. Though it aroused no open protest from the mine owners, STEG induced heavy bankruptcy among them and soon the small mines have disappeared. However, ore production managed by STEG has continuously increased thereafter, reaching its climax to the end of the 1800s, when about 93% of the iron and coal consumed in Transylvania was supplied by this company. Estimates of 1897 show that Banat produced 146,150 tons of iron, which was ten times the quantity extracted in 1855. Other metals were (in 1870): Au – 36 kg, Ag – 425 kg, Cu – 107 tons, Pb – 21 tons.

In 1920, STEG was overtaken over by a Romanian company: *Uzinele și Domeniile Reșița* (UDR) which was interested mainly in the iron ores from Ocna de Fier and in the coal deposits from Lupac, Doman, Secu and Anina – very close at hand supplies for the steel works in Reșița.

The rest is comparatively recent history. During the 1970s, remainings of the metal resources were still being extensively exploited, but afterwards, many of the south-western Banat ore deposits became too small and too poor to supply an ever increasingly requesting industry.

2. Field stops

Day 1

2.1 Field stop 1 – Skarns and mineralization at Băița Bihor

Coordinates: 46°30'0.92"N 22°37'37.18"E, elevation 640 m

Băița Bihor mine is the most diverse and economically important skarn deposit in the Northern Apuseni segment of the BMMB. The visit will include a presentation of the mining activities by S.C. Băița S.A. at their headquarters in Ștei (Fig. 15), and a field stop at the actual mining site, where both underground and quarry operations are taking place.

The mine is located in the upper course of Crișul Negru River where various lithologies belonging to the Bihor domain and Codru nappes are intersected by numerous igneous dykes rooted in a deep granodiorite-granite pluton. Detailed descrip-

Fig. 15. The headquarters of S.C. Băița S.A. in Ștei. A typical Soviet neo-classical architecture from the 1950s, still dominates the largest boulevard in Ștei. Here, a presentation of the Băița mine will be given to field trip attendants.

tions of the local stratigraphy and ore deposits are published in numerous works, *e.g.* Giuşcă (1937), Gherasi (1969), Cioflica *et al.* (1967, 1971, 1974, 1976, 1977, 1982), Cioflica & Vlad (1968, 1970, 1973a,b,c, 1977, 1980), Ştefan *et al.* (1988), Marincea (1999), Vlad & Cioflica (1994).

The sedimentary formations are structurally divided among two major tectonic units:

– The Bihor domain – is represented by a comprehensive sedimentary cover with (1) micro-conglomerates and lithic sandstones, pelites, limestones and marls (Hettangian–Sinnemurian); (2) fine or arenitic Farcu limestones (Oxfordian–Tithonian); (3) Albioara limestones (Upper Tithonian) and (4) limestones and bauxites (Barremian). The Bihor unit lies directly upon the Bihor main batholitic body and is largely affected by thermal and metasomatic metamorphism.

– The Codru nappes – contain lithic sandstones and siltites, pelites and clayey limestones (Permian), quartz sandstones and coarse litharenites (Werfenian), dolostones and clayey limestones (Anisian), micritic limestones (Ladinian) covered by a thick detrital sequence stretching to Lower Jurassic (Carnian–Hettangian).

The overthrusting of Codru nappes on Bihor domain at Băiţa Bihor is visible along the Blidar contact and Antoniu fault (Fig. 16).

The banatites are represented by a large intrusive body, composed mainly of granodiorite with subordinate granites, quartz microdiorites, syenites and various dioritic xenoliths (Stoici, 1983). Numerous dykes of rhyolites, rhyodacites, dacites, andesites, basalts, lamprophyres crosscut the entire area and form continuous outcrops extended over hundreds of meters. Dykes are 10–15 m wide and are generally oriented NW–SE, with steep inclinations of up to 80° (Fig. 17).

Contact metamorphism phenomena are widespread. The vertical extension of thermal and metasomatic transformations above the roof of the main intrusive body is estimated at 1.5 km, of which more than 1000 m are well documented from drill holes. Detrital and siltic Permian rocks are transformed in hornfels of various types, such as "spotted shales" (Cioflica *et al.*, 1980), blasto-pelitic, blasto-psamitic, porphyro- or granoblastic aluminous hornfels with illite-biotite-andalusite-cordierite-hematite, epidote-actinolite-tourmaline hornfels, calc-aluminous hornfels with plagioclase-diopside-grossular (Cioflica *et al.*, 1974; Stoici, 1983). Peraluminous hornfels

Fig. 16. Geological sketch map of Băiţa Bihor area (simplified after Stoici, 1974). 1) Permian (sandstones, siltites); 2) Anisian–Norian (a. limestones; b. dolostones); 3) Lower Jurassic (shales, sandstones, black limestones); 4) Oxfordian–Tithonian (limestones, dolostones); 5) Barremian (a. limestones; b. detrital rocks); 6) Upper Cretaceous–Paleogene (banatites: dykes: basalts, andesites); 7) Hornfels, skarns; 8) Metasomatic mineralized body; 9) Mining shaft.

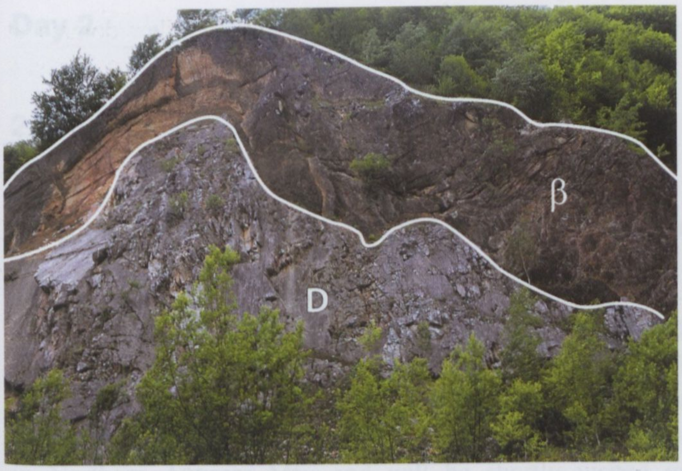


Fig. 17. Dyke of basalt (β) in Triassic dolomites (D), at Băița Bihor.

and extensive marbles formed on pure, alloclast-free carbonate rocks, add to this suite (Figs. 18, 19).

Pyrometasomatic transformations display extremely diverse compositions and geometries, reflecting a strongly differentiated paleosome. Proximal skarns following the magmatic contacts often grade into complicated branching morphologies suggesting infiltration processes along pre-existent rupture zones, such as thrust planes, or networks of fractures (distal skarns). Both magmatic and post-magmatic skarns have been described (*e.g.* Cioflica & Vlad, 1974; Stoici, 1983, Marincea, 1999), with the later type further divided into calcic skarns (scapolite-diopside-wollastonite-vesuvianite) and magnesian skarns (spinel-forsterite-chondrodite-phlogopite). The contact-metamorphic zone is affected by extensive boron metasomatism, especially in magnesian skarns developed on Triassic dolostones sequences (Marincea, 1999).

The mineralization is Cu- and locally, Pb-Zn-dominated, but with significant Mo + Bi + W + B. It develops in calcic skarns conformable to nappe overthrusting planes or to contacts between magmatic dykes and limestones, but mostly within a series of metasomatic columns (Baia Roșie, Antoniu, Hoanca Moțului, Bolfu-Tony), *i.e.*, quasi-cylindrical structures hosted in Triassic dolomites and extending over 400 m in depth. The columns are enveloped by a thick layer of dolomitic marbles with abundant magnesian borates (kotoite, suanite, ludwigite, fluoborite, szaibélyite) grading inwards to a zone with dedolomitized carbonate rocks and further to diopside-andradite-wollastonite skarns. The outer shell of the skarn zone is rich in galena and sphalerite, whereas the central parts are enriched in chalcopyrite, Bi sulphosalts, molybdenite and scheelite (Figs. 20, 21).

More than 100 minerals are cited from Băița Bihor (see Appendix 1), of which four have their type locality here: makovickyite – $Ag_{1.5}Bi_{5.5}S_9$ (Žak *et al.*, 1994), paděraite – $AgPb_2Cu_6Bi_{11}S_{22}$ (Mumme & Žak, 1985), szaibélyite – $Mg_2(B_2O_4OH)(OH)$ (Peters, 1861 *fide* Papp, 2004) and a recently discovered sulphosalt mineral (IMA 2008-053), yet to be published. Extensive studies on szaibélyite, fluoborite and other magnesian borates from this locality have been carried out by Marincea (1999, 2000b,c).

Szaibélyite from Băița Bihor is close to the end-member composition $Mg_2(B_2O_4OH)(OH)$. Up to 0.88 mol% sussexite (the Mn end-member), 1.06 mol% $Fe_2(B_2O_4OH)(OH)$ and 0.20 mol% $Ca_2(B_2O_4OH)(OH)$ were deduced on the basis of

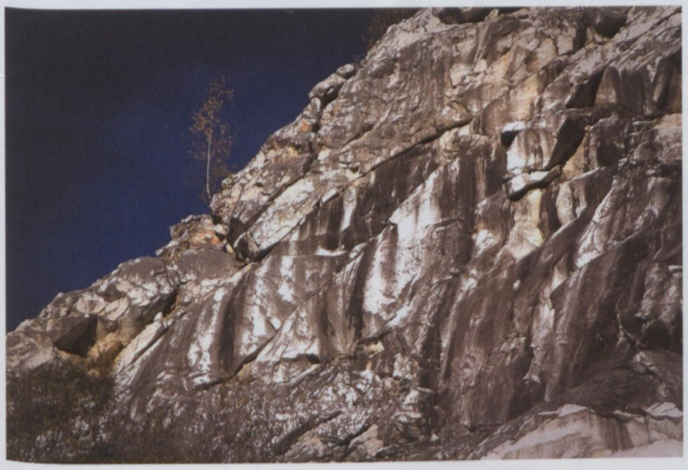


Fig. 18. Outcrop of recrystallized Cretaceous limestones at Băița Bihor.

Fig. 19. Small scale quarrying of marble at Băița Bihor.

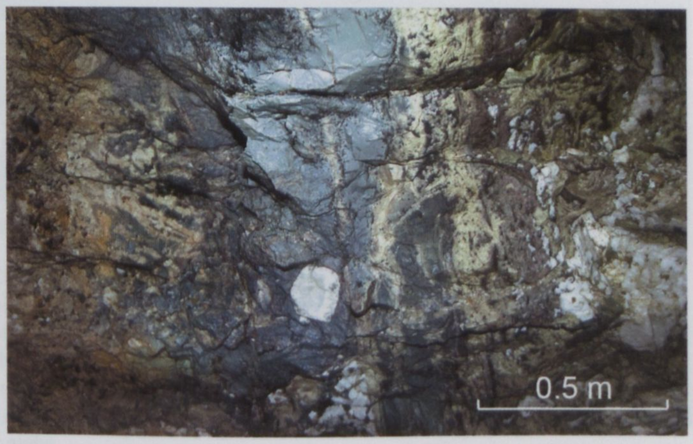


Fig. 20. Typical aspect of underground mineralization in diopside-garnet skarns (Antoniu metasomatic column, Băița Bihor).

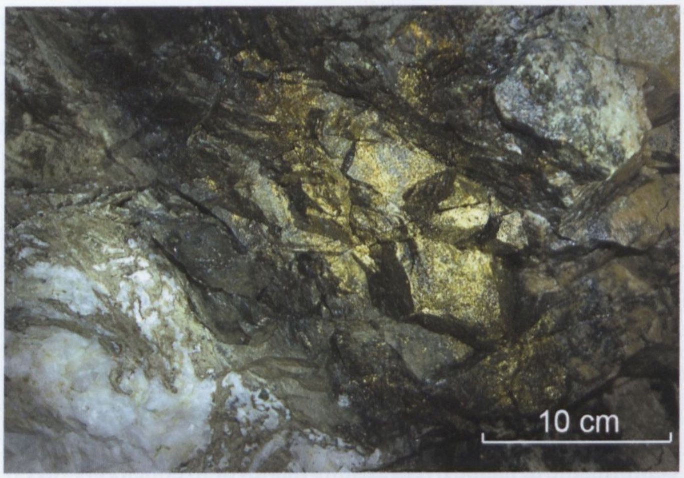


Fig. 21. Massive chalcopyrite and chalcocite in diopside-garnet skarns (Antoniu metasomatic column, Băița Bihor).

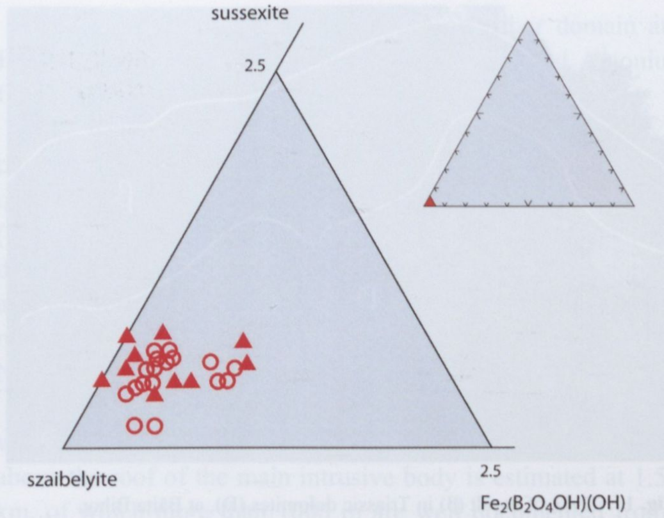


Fig. 22. Plots of compositions obtained by wet chemical analysis (triangles) and by electron microprobe analysis (circles), indicating the position of szaibélyite from Băița Bihor in the szaibélyite–sussexite–$Fe_2(B_2O_4OH)(OH)$ solid-solution series (redrawn from Marincea, 2001).

combined wet-chemical and electron-microprobe analyses (Fig. 22). The mineral is monoclinic, space group *P*21/*a*, *a* 12.559(18), *b* 10.402(12), *c* 3.132(8) Å and *b* 95.77(33)°. Szaibélyite from Băița Bihor is estimated to have developed at temperatures of 160–450 °C, pressures of 0.6–3 kbar, at relatively high activity of fluorine, and at low potentials of iron and manganese.

Fluoborite occurs in the outer zones of the metasomatic columns where it is closely associated with calcite, fluorite, chondrodite and norbergite in a paragenesis that also includes dolomite, magnesite, kotoite, suanite and ludwigite. Fluoborite forms acicular crystals in sheaf-like aggregates, generally enveloped by calcite. Temperatures of 380–450 °C and pressures of 0.6–3 kbar were estimated for fluoborite crystallization (Marincea, 2000c).

During the last decades Băița Bihor has become famous for its outstanding Bi sulphosalt assemblages. Makovickyite–cupromakovickyite exsolution textures, paděraite (observed compositions; Ilinca, 1998) – $Cu_{6.9}Ag_{0.2}Pb_{1.32}Bi_{11.5}S_{21.7}$,
hodrushite – $Cu_{7.8}Fe_{0.3}Ag_{0.2}Bi_{11.5}S_{21.5}$,
kupčíkite – $Cu_{7.8}Fe_{1.1}Ag_{0.1}Bi_{10.9}Sb_{0.1}S_{21.4}$,
lillianite – $Cu_{0.4}Ag_{0.9}Pb_{3.4}Bi_{5.1}Sb_{0.2}S_{11.6}$,
cosalite – $Cu_{0.6}Ag_{0.4}Pb_4Bi_{4.9}S_{11.9}$,
junoite – $Cu_{2.0}Ag_{0.1}Pb_{2.8}Bi_8S_{15.6}$,
cannizzarite – $Cu_{0.1}Ag_{0.3}Pb_{3.7}Bi_{5.8}Sb_{0.1}S_{12.6}$,
heyrovskýite – $Pb_{6-2x}Ag_xBi_{2+x}S_9$,
vikingite – $Pb_{4.5-2x}Ag_xBi_{2+x}S_{7.5}$,
galenobismutite – $PbBi_2S_5$,
bismuthinite derivatives (pekoite, gladite, salzburgite, paarite, krupkaite, lindströmite, emilite, hammarite, friedrichite, aikinite), emplectite – $CuBiS_2$, wittichenite – Cu_3BiS_3 and numerous tellurides and sulphotellurides outline the paragenetical complexities of this occurrence (Fig. 23).

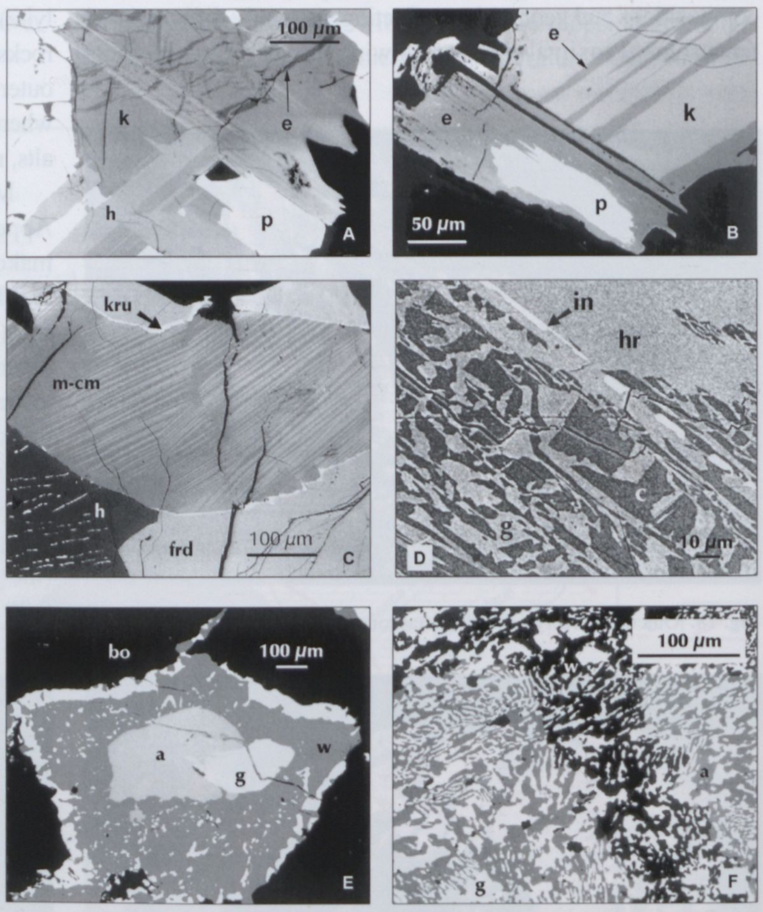


Fig. 23. BSE images of bismuth sulphosalt assemblages from Băița Bihor. A) Fine parallel intergrowths of hodrushite (h) and kupčíkite (k) associated with paděraite (p); emplectite (e) is a late replacing phase and only affects kupčíkite. B) Late replacement of paděraite (p) and kupčíkite (k) by emplectite (e). C) Exsolutions of makovickyite-cupromakovickyite (m-cm) associated with hodrushite (h), krupkaite (kru) and friedrichite (frd). D) Decomposition of heyrovskýite (hr) into cosalite (c) and galena (g); the white inclusions are ingodite (i). E) Composite grains with aikinite (a) core surrounded by galena (g) and wittichenite (w) exsolutions, in bornite (bo). F) Vermicular intergrowths of aikinite (a) wittichenite (w) and galena (g).

Day 2

2.2 Field stop 2 – Magnesian borates in the skarns of Dealul Gruiului – Pietroasa.

Coordinates: 46°38'6.27"N – 22°30'35.48"E, elevation 312 m

The occurrence is located in a large area of magnesian hornfels at the contact between Pietroasa granitoid body and Anisian dolostones belonging to Codru nappe system, close to the confluence of Aleu and Sebişel (Fig. 24). The Pietroasa magmatic body is one of the most important banatitic massifs in Northern Apuseni Mts. and will be shortly visited in Pietroasa quarry (Fig. 25), on Crişul Pietros Valley, prior to reaching the borate occurrence on Aleu Valley. The massif has been assigned to the second magmatic cycle (Table 1) in the Apuseni Mts. (Ştefan *et al.*, 1988). Rocks range from granites to quartz diorites, but granodiorites are predominant (Istrate & Udubaşa, 1980; Ionescu 1996; see also Stop 2 in Ionescu & Hoeck, 2010). Igneous (coarse granodiorites, microgranodiorites, dolerites, diorites), regional metamorphic (quartzite, chlorite schists, amphibolites, gneisses) and sedimentary (graywackes, sanstones, carbonate rocks, clays) xenoliths (Fig. 25, inset), ranging in size from centimetres to tens of meters, are abundant in the peripheral parts of the intrusion (*e.g.* Stoicovici & Sălăgean, 1970; Ştefan *et al.*, 1988; Ionescu, 1996a; Ionescu & Hoeck, 2010).

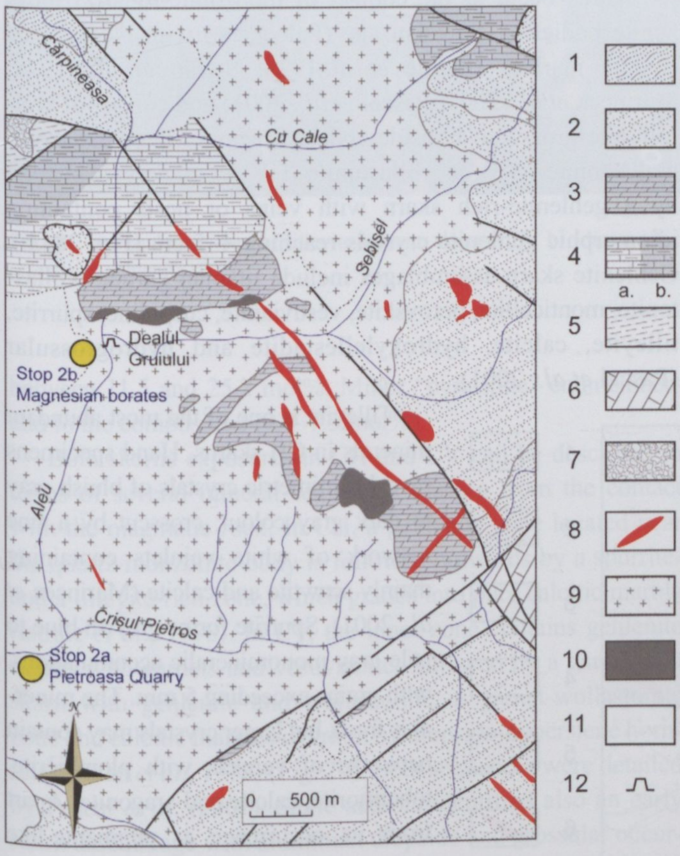


Fig. 24. Simplified geological map of Pietroasa area (redrawn after Bleahu *et al.*, 1985; Marincea, 2006). 1) Permian schistose clays and sandstones; 2) Lower Triassic quartzitic sandstones; 3) Anisian recrystallized dolostones; 4) Ladinian–Norian, a – black cherty limestones, b – recrystallized; 5) Lower Lurassic marls, clays, limestones; 6) Barremian–Aptian limestones; 7) Upper Cretaceous breccias with clay-sandstone matrix; 8) Upper Cretaceous dykes (rhyolites, granodiorites, (micro)granites, andesites); 9) Upper Cretaceous banatitic intrusive rocks (granodiorites, granites); 10) Skarns; 11) Quaternary deposits; 12) Mine adit.

The intrusion of the granodioritic magma into the surrounding Mesozoic dolomites, limestones and other sediments generated extended and complex contact aureoles, comprising hornfels, skarns and hydrated metasomatic rocks.

Magnesian skarns with forsterite, diopside and garnet develop discontinuously along the contacts between the granodiorite body and Ansian dolostones (Ionescu, 1996a,b). Periclase, spinel and scheelite are common accessories of such skarns. A large number of hydrated minerals, such as vesuvianite, phlogopite, epidote, talc, brucite, illite, serpentine minerals and zeolites a.o. accompany skarn assemblages. Younger veins with quartz, magnesite, sepiolite, calcite, pyrite, pyrrhotite, sphalerite, chalcopyrite, galenobismutite, and galena are also common.

Moderate boron-fluorine metasomatism affects the hornfels groundmass. The composition of hornfels is dominated by calcite and dolomite and reflects the nature of the premetamorphic Anisian-Norian sedimentary involved in the contact processes. Magnesium content ranges from 0.68 to 5.12 mol% $MgCO_3$ in calcite and from 49.83 to 51.02 mol% $MgCO_3$ in dolomite (Marincea, 1993). Beside carbonates, forsterite, spinel, clinohumite, chondrodite, tremolite, phlogopite, clinochlore and serpentines are the common components of magnesian hornfels. Instead, calcic hornfels contain apophyllite, wollastonite and epidote.

Boron metasomatized areas contain ludwigite, szaibélyite and suanite. Ludwigite occurs as millimetric, needle-like crystals in nodular or fibro-radiary aggregates, disseminated in the carbonate mass. Szaibélyite is a magnesian end-member of the

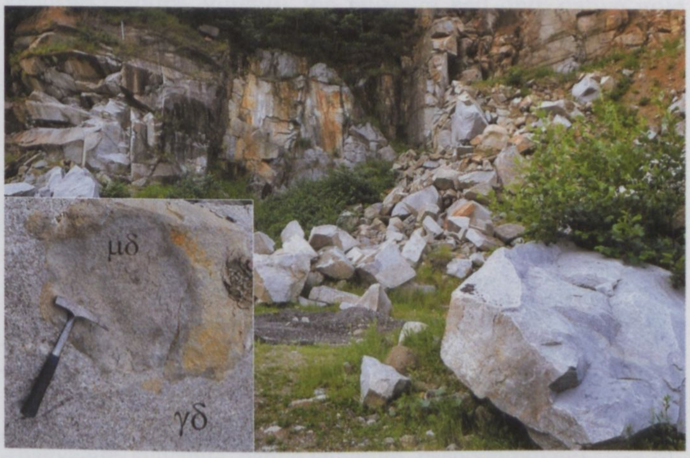


Fig. 25. Granodiorite quarry at Pietroasa. The detail in the inset shows microdiorite xenolith (μδ) in granodiorite (γδ).

szaibélyite-sussexite series. It typically occurs with a fibrous habit in the inner most zones of the boron-bearing sequences, where makes up to 60% of the rock volume (Fig. 26). Anhedral to subhedral relics of suanite up to 1 mm in length and 0.5 mm in width occur frequently in the szaibélyite masses, which are normally bordered by dolomite (Marincea, 2006). Suanite shows no significant deviation from its $Mg_2B_2O_5$ composition.

Retrogressive replacements of suanite by szaibélyite, of chondrodite by serpentine and of spinel by clinochlore are widespread. It is estimated that suanite formed within a range of temperatures between 350 and 500-550 °C. In view of retrogressed suanite and spinel (transformed in szaibélyite and clinochlore, respectively), the maximum pressure must have been lower than 3 kbar. The absence of calcium borates, suggests, however, that the pressure must have exceeded 0.6 kbar (Marincea, 2006).

Fig. 26. Szaibélyite hand specimen. Dealul Gruiului, Pietroasa.

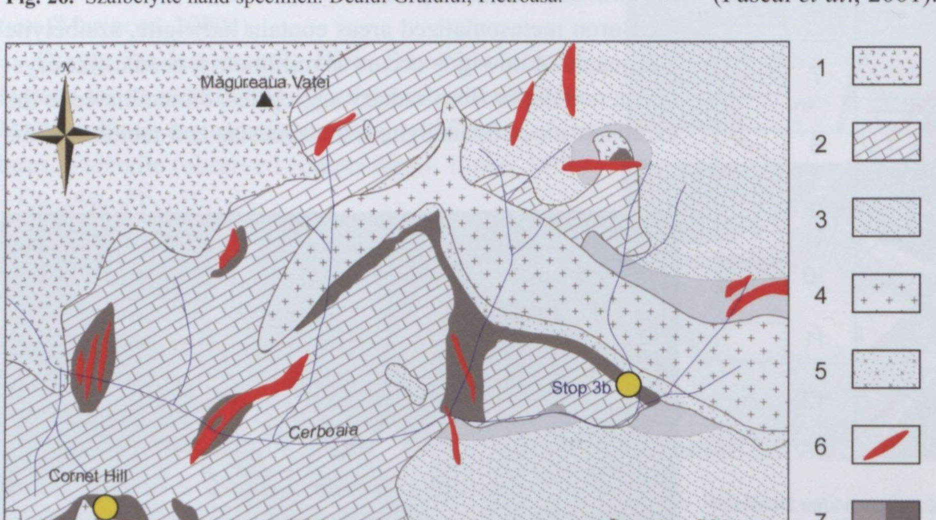


Fig. 27. Schematic geological map of Măgureaua Vaţei area (redrawn after Ştefan *et al.*, 1978). 1) Mesozoic ophiolites; 2) Upper Jurassic recrystallized limestones; 3) Upper Cretaceous clays, sandstones and conglomerates; 4) Banatites: monzonites, monzodiorites; 5) quartz-monzonites; 6) monzonite dykes; 7) a. Pyroxene hornfels, b. Calcic skarns.

Among boron affected areas, large brucite-bearing zones occur in Anisian dolomitic marbles. The contact of granodiorites with the Anisian dolomites shows a zoned structure *i.e.* a transition from Mg-skarns to brucitic zones and finally to dolomites. Brucite-bearing zones occur only at some distances from the contact and are irregular, sometimes lens-shaped. They range from several metres up to tens of metres in width and from tens to hundreds of metres in length (Ionescu & Hoeck, 2005).

2.3 Field stop 3 – High-temperature calcic skarns at Cornet Hill and Cerboaia Valley (Măgureaua Vaţei area).

Coordinates: 46°13'40.61"N – 22°31'17.86"E, elevation 453 m

The high-temperature skarn occurrence at Măgureaua Vaţei is one of the very few of the kind in the BMMB, but definitely the most spectacular exhibit of gehlenite, tilleyite and spurrite. Two skarn outcrops will be visited during this stop: Cornet Hill (CH) and Cerboaia Valley (CV) (Fig. 27).

Skarns occur at the contact of monzonite-(quartz) monzonite bodies of Ypresian age (Paleocene) with Neojurassic calcitic marbles (Istrate *et al.*,1978; Ştefan *et al.*, 1978; Marincea *et al.*, 2001; Pascal *et al.*, 2001) and consist of wollastonite-grossular-diopside endoskarns and tilleyite-spurrite-wollastonite (CH) or wollastonite (CV) exoskarns, separated by a gehlenite-rich skarn with veins or nests containing idiomorphic gehlenite crystals reaching 4–5 cm (Fig. 28a,b). Gehlenite skarn assemblages include titanian garnet, wollastonite, monticellite, perovskite, vesuvianite, cuspidine, spurrite, tilleyite, calcite, hydroxylellestadite and hydrogrossular (Pascal *et al.*, 2001).

Tilleyite is one of the most abundant minerals in CH skarns. Hand specimens reveal centimetric crystals of bluish gray to dark gray colour, crosscut by a fine network of white veinlets containing mainly scawtite and calcite (Marincea *et al.*, 2001). Spurrite forms greyish blue to pale gray monomineralic accumulations, with grains exceeding 5 mm. The mineral is fresh, but larger crystals may contain networks of veinlets with plombièrite, tobermorite, calcite and aragonite. Apart from its occurrence as pegmatite-like veins and nests, gehlenite develops as clusters interstitial to tilleyite, or embedded in a matrix of vesuvianite which invades along cleavage planes. Åkermanite content in gehlenite varies between 25.7 and 40.9 mol% (*op. cit.*). Several generations of grossular have been identified, with andradite content ranging

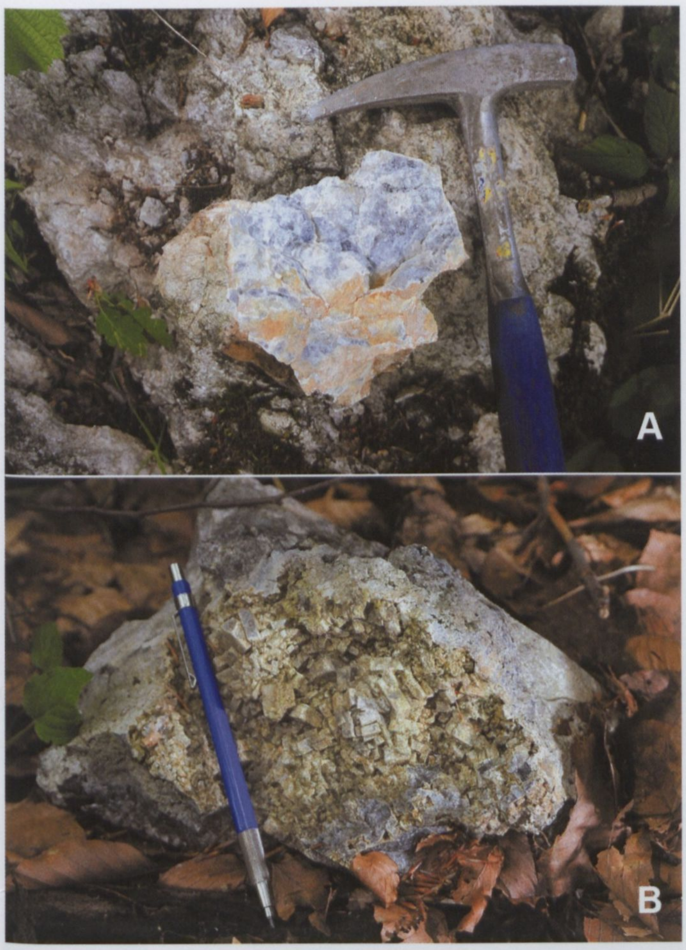


Fig. 28. a) Hand specimen of tilleyite-spurrite skarn (CH). b) Idiomorphic crystals of gehlenite (CV).

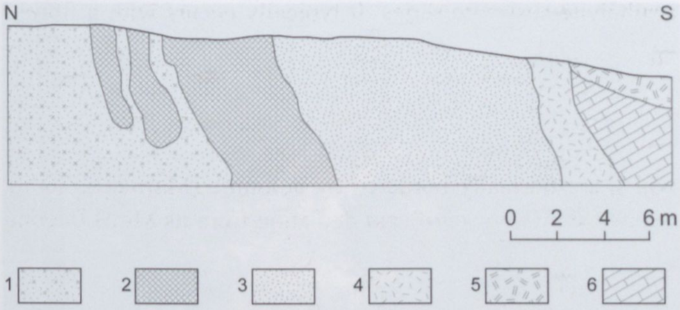


Fig. 29. Skarn zoning in Cerboaia Valley (redrawn after Ştefan *et al.*, 1978): 1) Quartz-monzonite; 2) Gehlenite skarn with vesuvianite and garnets; 3) Garnet skarn with gehlenite and wollastonite; 4) Garnet-wollastonite skarn; 5) Pyroxene hornfels; 6) Calcitic marble.

between 11.5 and 25.2 mol%. Minor "pyralspite" endmembers add to the composition (0.8–7.5 mol%).

Both skarns exposures in CH and CV can be described in terms of several mineral sequences starting from the contact with the magmatic rock. In CH, a gehlenite zone located near the quartz-monzonite body is followed outwards by a spurrite- and a tilleyite-rich zone, which grades into pure calcitic marble (Istrate *et al.*, 1978). In CV, the inner zone contains gehlenite skarns with garnets and vesuvianite, followed by a garnet-rich skarn with gehlenite and wollastonite, a garnet-wollastonite zone and calcitic marbles overlain by diopside-hyperstene hornfels (Ştefan *et al.*, 1978) (Fig. 29). Both sequences were detailed by Pascal *et al.* (2001). Same authors identified also an early skarn assemblage with aluminian diopside and grossular occurring either as veinlets in marble or as relics in endoskarns and interpreted it as a result of a CO_2-rich fluid circulation inducing depletion of Si, Fe, Na and K while leaving inert Mg, Al and Ti in place. A subsequent high temperature (750 °C) fluid precipitated gehlenite and titanian garnet on previously formed endoskarns and spurrite – wollastonite (CH) or wollastonite (CV) exoskarns. Pascal *et al.* (2001) estimated a CO_2 pressure lower than 16 bars (CH) and 26 bars (CV), and a H_2O pressure less than 750 bars. Leaching of Mg, Al and Ti from endoskarns and mobilization of Si and Ca induced new precipitation at the inner limit of exoskarns. The paragenetic sequence ascribable to this fluid ended with the deposition of tilleyite, which partly replaced spurrite and wollastonite (CH), and with high-temperature recrystallization (710 °C). Monticellite-gehlenite assemblages developed in the gehlenite-rich skarns, followed by vesuvianite ± wollastonite and grossular.

Clinopyroxene with extremely high content of CaTs ($CaAl_2SiO_6$) and esseneite ($CaFe^{3+}AlSiO_6$) components has been recognized as veinlets and inclusions in the marble very close to the intrusive contact, or as very small inclusions in wollastonite-grandite skarns, close to the gehlenite skarn in Cerboaia Valley (Pascal *et al.*, 2005). Same authors described a similar occurrence in the gehlenite-rich skarn in Cornet Hill.

2.4 Field stop 4 – The Museum of Gold, Brad.

Coordinates: 46° 8' 7.23"N – 22°47' 38.90"E

The museum was founded in 1912 but many of the exhibits had been already part of a mineralogical collection ever since the 19th century. Initially, the museum had only native gold samples gathered from various mines in Brad region, but later, through sample exchange and donation, the collection diversified both mineralogically and geographically.

The total number of samples is estimated at 2500, of which approximately 1000 are native gold, many of unusual size and morphology (Fig. 30). The long history of mining in the Golden Quadrilateral of Apuseni Mts. is well documented in the museum. A remarkable collection of documentary photographs by Basil Roman, showing mining activities before the Second World War is also on display.

The museum hosts also a systematic mineralogical collection, stressing upon characteristic local occurrences and type localities (nagyágite, sylvanite, native tellurium, pseudobrookite).
By the time of drafting this guide, the museum was still under a long-delayed renovation.

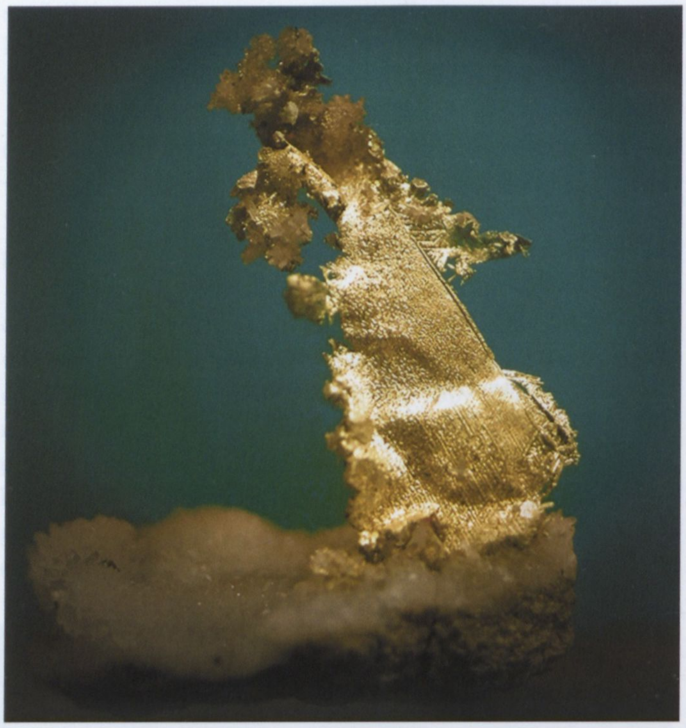


Fig. 30. Gold leaf (approx. height 6 cm). The Museum of Gold, Brad.

2.5 Field stop 5 – St. Mary's church, 13th century – Sântămaria Orlea

Coordinates: 45°35'1.72"N – 22°57'56.51"E

St. Mary's church was founded in the late 13th century by princes belonging to the famous Cândeşti (Kendeffi) family. The sanctuary was meant to serve a Roman Catholic community of settlers. Soon after foundation and until the mid-16th century, the church was used by the local Greek Orthodox population. A first layer of interior painting of Byzantine inspiration dates from this period. By 1559, documents mention that the church changed cult again, and that religious service was given by a Reformed priest named Martin (crestinortodox.ro)

The architecture points to late Romanic style with added influences of early Gothic (Fig. 31). The interior hosts a vast mural painting ensemble dating mainly from three different periods and combining Byzantine and Italian Renaissance influences. The first paintings depicted ten Catholic consecration crosses, later covered by 14th century Byzantine paintings in reddish-brown hues (Fig. 32). The altar painting, showing six of the Apostles, is believed to date back to the 15th century and to share some late Byzantine influences. Successive paintings added to these early decorations, including a scene on the right side of the entrance, showing St. Elizabeth of Hungary.

The church is one of the most interesting examples of overlapping and coexisting Byzantine and Latin history, iconography, styles and inscriptions.

Fig. 31. St. Mary's church in Sântămăria Orlea, late 13th century.

2.6 Field stop 6 – Densuş Church – 13th century

Coordinates: 45°34'52.21"N – 22°48'29.72"E

The Orthodox church from Densuş (Fig. 33) represents one of the oldest Christian sanctuaries in Romania (Rusu, 2008). Based on late Romanesque and early Gothic architecture, the church was dated in the second half of the 13th century (Rusu, 2008; Rusu & Burnichioiu, 2008). Its origins are however controversial. Some scholars believed that the initial sanctuary was a mausoleum dedicated to general Longinus Maximus who was killed during the Roman-Dacian wars, whereas others considered that it was a temple dedicated to Mars. The new archaeological researches concluded that there are no antique antecedents for the building, except for some ashlars taken for a neighbouring Roman villa (Rusu, 2008).

Surely, the church has undergone numerous modifications, especially at the end of the 13th century. The building materials are most diverse and unusual, especially in what regards

Fig. 32. 14th century mural painting in St. Mary's church, Sântămăria Orlea.

the borrow sources: alluvial boulders, limestones, brick work with Roman inscriptions, fragments of Roman buildings and monuments, columns, zoomorphic ornaments, funeral stones, sewage pipes, *etc.*, most probably taken from the ruins of Ulpia Traiana Sarmizegetusa nearby (Fig. 34).

The church has Roman style architecture with early Gothic influences. It gives the impression of a surprisingly large interior when compared with the overall exterior dimensions. Interior Byzantine painting by an artisan named Stefan, dates from the mid-15th century.

2.7 Field stop 7 – Ulpia Traiana Sarmizegetusa – the Roman capital city of Dacia, 2nd and 3rd centuries.

Coordinates: 45°31'5.06"N – 22°47'12.16"E

The historical site of Ulpia Traiana Sarmizegetusa preserves the remains of the first Roman capital city of Dacia (Figs. 35 and 36). The settlement was founded around 106–110 A.D, by the first governor of the province, Terentius Scaurianus, soon after Emperor Trajan conquered Dacia. The place chosen for building the new administrative centre of the colony was that of the former strategic military camp of the Vth Macedonica Legion.

During Emperor Hadrianus (117–138 AD) the city took the name of Ulpia Traiana Augusta Dacica Sarmizegetusa in celebration of the Dacian capital Sarmizegetusa Regia, located approximately 40 km to the east. The origin of the name Sarmizegetusa could only be speculated as the ancient Dacian language was lost. A probable explanation was that it came from "zermi" (rock, height) and "zeget" (palisade, fence, fortification), thus suggesting a name for a "High Fortress" which characterized accurately the geographical position of King Decebal's fortified city in Orăştie Mts. From 222 and until 235 AD the city was ranked as *metropolis* and reached a population of approximately 25,000 (cimec.ro/Arheologie/UlpiaTraiana/descriere/sit.html)

The archaeological complex includes the ruins of all major edifices of the former capital: the Forum, the amphitheatre, palaces, workshops and residential buildings.

Fig. 33. Densuş church, 13th century. General view.

Fig. 34. Roman columns added to the construction of Densuş church.

Fig. 36. Fragments of Roman inscriptions and other archaeological exhibits at Ulpia Traiana Sarmizegetusa historical site.

Fig. 35. Roman ruins at Ulpia Traiana Sarmizegetusa.

dislocate and include parts of previously emplaced rocks. The dykes and enclaves consist of porphyritic microdiorites with large zoned plagioclase phenocrysts within a microgranular groundmass of plagioclase and amphibole. Some concentrations of actinolitic amphibole could represent pseudomorphs after pyroxenes. Quartz xenoliths with actinolite coronas may also be found. A certain degree of autometamorphism is suggested by the alteration of the primary amphiboles and by the argillization of the plagioclase phenocrysts.

The granodiorites show typical features for the Bocşa$_3$ phase. Here, they exhibit a marginal facies and a porphyritic texture. They contain recurrently zoned plagioclase phenocrysts, biotite, actinolite and subordinately, corroded quartz within a groundmass of K-feldspar, plagioclase and quartz (Russo-Săndulescu, 1993).

Day 3

2.8 Field stop 8 – Banatite outcrop, Bocşa

Coordinates: 45°22'46.43"N – 21°44'37.34"E, Elevation 163 m

The field stop is intended to give a first sight of banatitic rocks at their *locus typicus*, in Banat region. A drive escarpment on the left bank of Bârzava river shows the relations between successive intrusive phases belonging to phase B (Table 1).

The outcrop (Fig. 37) displays ocular gneisses of Tâlva Drenii formation (belonging to the Supragetic Nappe), crossed by a first generation of small dykes of basic igneous rocks, reaching up to 1–2 m in width (labelled with number 2 in Fig. 37). The dykes are followed by a second magmatic stage with granodiorites, which

2.9 Field stop 9 – Gruescu mineralogical collection, Ocna de Fier

Coordinates: 45°20'36.66"N – 21°46'38.18"E

General remarks on Ocna de Fier area. This third day of the RO-5 field trip will be entirely devoted to the renowned skarn occurrence of Ocna de Fier. The mineral wealth of the village inspired the local official heraldry and Ocna de Fier is probably the only locality in Romania to have chosen mineralogical symbolism in its city coat of arms (Fig. 38). Although the literature often mentions "Dognecea–Ocna de Fier" banatites, skarns or skarn deposits, the southern part of the area, *i.e.*

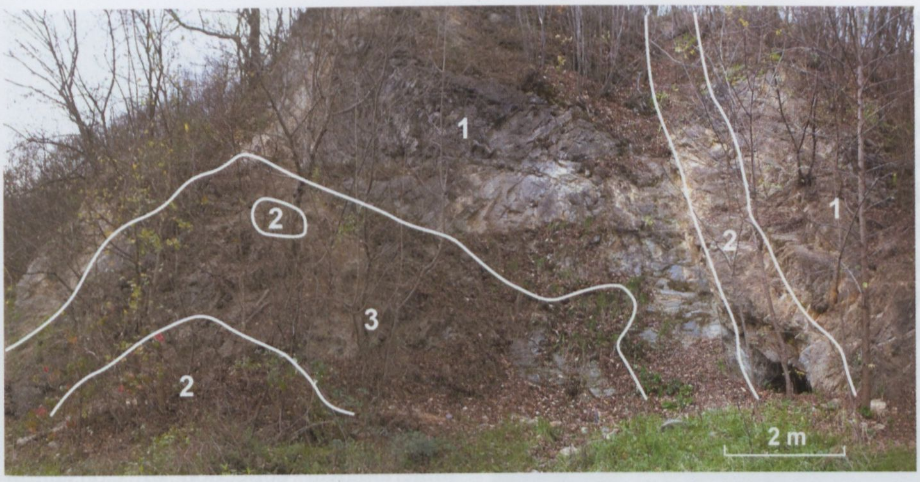
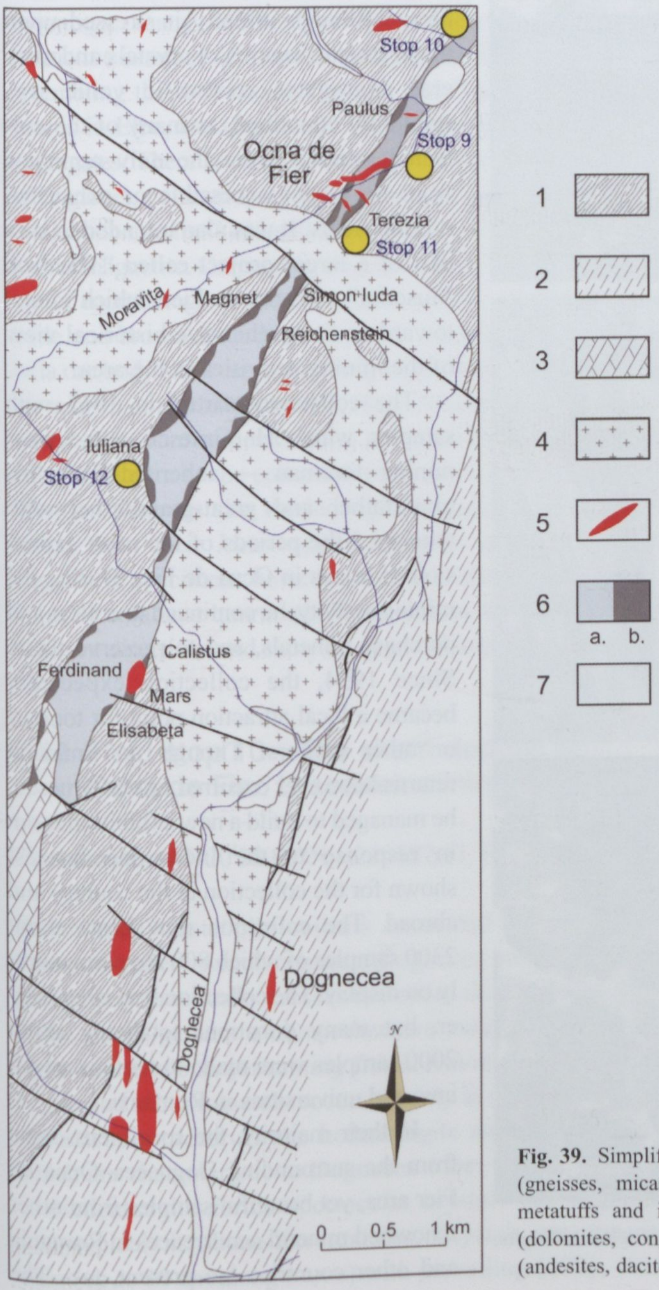


Fig. 37. Field relations between ocular gneisses of the Supragetic Nappe (1) and banatitic microdiorite dykes (2) and granodiorites (3) (after Ilinca *et al.*, 1993).

Fig. 38. Crystallographic heraldry at the entrance in Ocna de Fier.



Dognecea will not be accessible to our route. However, the two localities shared largely similar magmatic and contact metamorphism evolution.

The basement of Dognecea–Ocna de Fier consists of Precambrian and Lower to Middle Palaeozoic crystalline schists of the Bocşa Nappe (belonging to the Supragetic unit) *i.e.*, the Bocşiţa-Drimoxa formation. The sedimentary formations show typical features for the ridge-type evolution; they are represented by a discontinuous and condensed cover of mainly Cretaceous (Barremian–Aptian) iron-deficient carbonate rocks forming a narrow, N–S extended, syncline structure (Ezeriş-Cârnecea) (Fig. 39).

Banatites belonging to the Bocşa$_3$ phase (Table 1), occur within a large granodioritic body reaching a maximum width of 5 km. The main intrusion is accompanied by small bodies and enclaves of more basic rocks (monzodiorites, quartz diorites), which might represent previous intrusive phases with respect to the granodiorites. Vein rocks subsequent to the main intrusion, *i.e.* andesites, lamprophyres, dacites and rhyolites (Russo-Săndulescu *et al.*, 1986a) are also discordantly spread across the area.

Around the main granodioritic body, various thermal contact associations, as well as pyro- and hydrometasomatic assemblages developed. Non-carbonate rocks were partly replaced, forming silica-aluminous hornfels and locally, grossular-bearing lenses. On the expense of carbonate rocks, mainly garnet, wollastonite and pyroxene skarns formed. These calcic exoskarns are generally banded and parallel to the contact between the crystalline schists or igneous bodies and the calcitic marbles. Subsequent retrograde hydrothermal alteration products of the skarn assemblages together with iron oxide and sulphide mineralization are widely spread in the area.

Fig. 39. Simplified geological map of Ocna de Fier–Dognecea (after Vlad, 1974): 1) Precambrian (gneisses, micaschists, amphibolites); 2) Devonian– Carboniferous (metapellites, metasiltites, metatuffs and isolated bodies of granodiorites and gabbros); 3) Jurassic–Middle Cretaceous (dolomites, conglomerates, sandstones); 4) Banatites: plutonic rocks (granodiorites); 5) Dykes (andesites, dacites, rhyolites, lamprophyres); 6) a – Marbles, b – Skarns; 7) Quaternary deposits.

About 110 minerals were described in Dognecea–Ocna de Fier (see Appendix 1), many of them quite rare or sole occurrences in Romania. Ocna de Fier is the type locality for ludwigite and veszelyite. A modern description of ludwigite is provided by Marincea (1999). A historical review of mineral phases described at Ocna de Fier can be found in Ilinca *et al*. (1993).

As in the case of Băița Bihor, rich Bi sulphosalt assemblages occur throughout the skarn deposit. Detailed mineralogical descriptions of various bismuthinite derivatives, minerals of the cuprobismutite family (paděraite, hodrushite, cuprobismutite), galenobismutite, lillianite homologues (heyrovskýite, lillianite), members of the pavonite homologous series (makovickyite, cupromakovickyite) as well as a comprehensive telluride and sulphotelluride association with kawazulite, bohdanowiczite, hessite, volynskite and their intergrowths, are given in Ciobanu & Cook (2000), Cook & Ciobanu (2001) and Ciobanu *et al*., (2004). Cosalite, proudite, high-Ag neyite and felbertalite are also important members of the Bi sulphosalt assemblages.

Ocna de Fier remains one of the few skarn deposits where nice hand specimens of rare minerals can still be found and collected (Fig. 40).

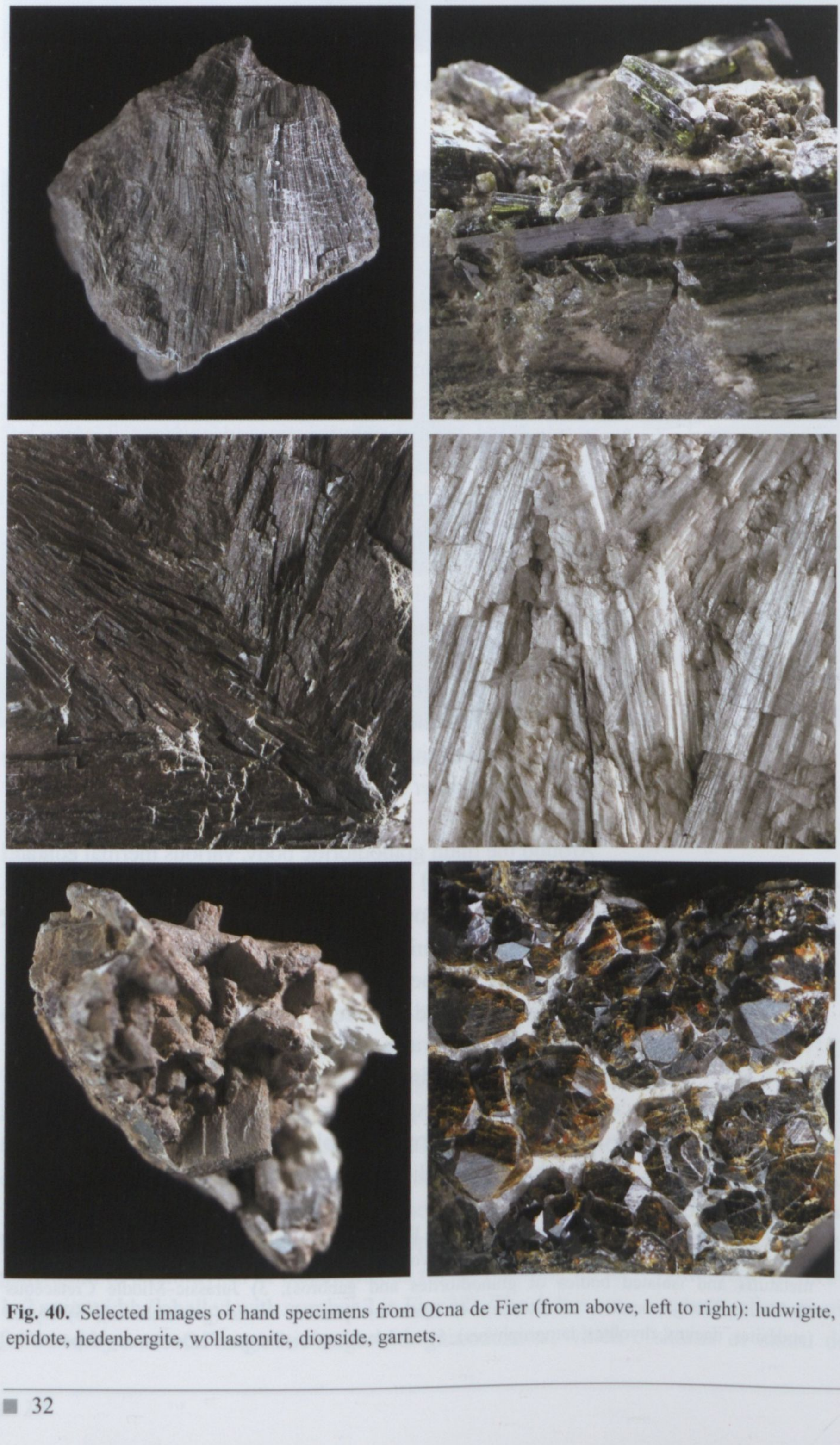


Fig. 40. Selected images of hand specimens from Ocna de Fier (from above, left to right): ludwigite, epidote, hedenbergite, wollastonite, diopside, garnets.

The mineralogical collection. The private mineralogical collection of Constantin Gruescu (Fig. 41) was intended to host the most representative mineral samples gathered from local banatite contact aureoles. Although initially it stressed upon the aesthetic features of crystals and mineral aggregates, scientific value was implicitly contained, as many of the collected samples were the only remnants from no longer accessible or exhausted mining fields. It was also intended to be a part of a larger project called "The Iron Museum" of Ocna de Fier, which aimed towards a comprehensive historical view of the mining activities in the area.

The collection started in 1945 with samples, which Mr. Gruescu — a former mining foreman — inherited from his grandfather and great-grandfather who witnessed the periods of top most expansion of mines in Ocna de Fier. During the mining activity, he continued to collect and purchase minerals, and to preserve them. Since 1954, the collection expectedly became a local attraction point for tourists or other visitors. Though no financial returns have ever occurred to Mr. Gruescu, he managed to build a new exhibition room in response to the increasing interest shown for the collection in the country and abroad. The collection now hosts about 2300 samples of which 800 are permanently on display. The collection was even larger, but many donations totalizing about 2000 samples were made to various museums and universities in Romania.

In their majority, the specimens come from the surrounding Dognecea–Ocna de Fier area, yet beautiful samples from other renowned mineral occurrences in Romania and other countries are present, too. The

Fig. 41. Constantin Gruescu in his mineral collection at Ocna de Fier.

collection hosts over 100 calcite crystallographic forms and twinnings, many of them of quite impressive dimensions. Attractive samples of hematite with rare crystallographic forms resembling the well-known Ginevro and Capo Calamita occurrences in Elba, are specifically intergrown in "iron roses"-type aggregates. There are also spectacular magnetite pseudomorphs after garnet, concretionary magnetite aggregates in the form of "stalactitic curtains" and odd dolomite pseudomorphs after octahedral magnetite. Garnets are largely represented through a variety of morphological and chromatic aspects: melanite, demantoide and brown andradites. Diopside samples from the Simon Iuda ore body show large, perfectly shaped crystals, which made the subject of numerous studies. Huge crystals of phlogopite and many other rare minerals such as todorokite, manjiroite and palygorskite make the collection even more interesting. Special attention deserves also the ludwigite samples which were collected from their *locus typicus* (Magnet quarry). The most impressive specimens however, are the extremely rare co-axial twins of columnar quartz which sometimes develop along three different directions and show no apparent supporting point.

2.10 Field stop 10 – The skarn deposit at Ocna de Fier. Ursoanea mining waste dump

Coordinates: 45°20'58.80"N – 21°46'2.51"E, Elevation 270 m

The mining waste pile collects excavated material from a transport gallery which connects Dognecea and Ocna de Fier. The gallery practically crosses the entire skarn area so that its waste dump gathers a comprehensive suite of minerals and rocks of the two major mining fields. Among phlogopite, ludwigite and other minerals occurring only at Ocna de Fier, special attention deserves the hedenbergite and ilvaite samples which are characteristic to Dognecea zone.

Hedenbergite forms spectacular crystals and aggregates with typical fish-bone-like textures. Crystals are unusually large (up to 10 cm along *c* axis) with prevailing {100}, {010}, {110}, {021}, {001}, {221} and {101} forms. Chemical compositions given by Vlad & Vasiliu (1969) and Vlad (1974) indicate manganoan, magnesian-manganoan, ferrian-manganoan and ferrian-magnesian varieties of hedenbergite.

Ilvaite from Dognecea was firstly described by Vlad (1969) and re-examined by the same author in 1974. Wet chemical analysis by these authors indicated unusually large MnO contents. Ilinca *et al.* (2006) identified ilvaite samples systematically exceeding 0.5 *apfu* Mn, suggesting the presence of the recently discovered mineral manganilvaite (Zotov *et al.*, 2005, Bonev *et al.*, 2005). Average chemical composition (in wt%; parentheses read as average values and standard deviations, respectively) indicated: Si: 13.39–14.09 (13.92; 0.15), Al: 0.00–0.27 (0.09; 0.11), Fe: 32.88–34.53 (34.62; 0.64), Mn: 7.30–9.17 (7.85; 0.54), Mg: 0.00–0.26 (0.07; 0.10), Ca: 9.86–10.64 (10.26; 0.22). Manganilvaite from Dognecea is a $P\ 2_1/a$ polymorph (*a* 13.014 Å, *b* 8.846 Å, *c* 5.848 Å, *b* 90.34°) with significant ordering of Fe^{2+} and Fe^{3+} among Me11 and Me12 structural sites. Local paragenetical relations and various published correlations between the ordering parameter and the temperature of formation, suggest that Mn-ilvaite from Dognecea represents a reaction product of 6 hed + 4 mgt + 3 $H_2O \rightarrow$ 6 ilvaite + ½ O_2, formed at temperatures not exceeding 300 °C, and in conditions of relatively low fO_2.

2.11 Field stop 11 – The skarn deposit at Ocna de Fier. Terezia quarry

Coordinates: 45°20'19.71"N – 21°46'7.61"E, Elevation 332 m

The quarry opens mainly calcic and magnesian skarns with superposed iron oxides (magnetite and hematite) and borate (ludwigite) mineralization. The host rock is represented by coarse-grained dolomite marbles. Old references mentioned by Codarcea (1931) and Kissling (1967) speak about native bismuth, bismuthinite, greenockite, sphalerite and stibnite.

The north-eastern wall of the quarry exhibits a broad picture of metasomatic zoning around a porphyritic diorite apophysis: diopside – andradite+diopside – ludwigite – serpentines (chrysotile, lizardite) – dolomitic marble. The iron ores were mined in the 19th century; they are located in andradite-dominant skarns where they form specific diffusion metasomatic intergrowths, described by Kissling (1967) as "orbicular" or "Liesegang textures". Such textures consist of magnetite (frequently pseudomorph after garnet or hematite), hematite and calcite or dolomite.

The main mineralogical interest of Terezia quarry resides in skarn and magnesian or calc-magnesian pseudoskarn minerals such as diopside, phlogopite and palygorskite.

Diopside crystals provided many collection specimens. Their dimensions (up to 8 cm along *c*) favoured numerous crystallographic studies (*e.g.* Kissling, 1967, 1971). Frontal pinacoids {100}, lateral pinacoids {010} as well as third order prisms species: {110}, {210} or {120} prevail among the 16 crystallographic forms described. Wet chemical analyses reported by Kissling (1967) show a relatively large isomorphism in the M1 sites where Mg^{2+}, Mn^{2+} and Fe^{2+} share different participations.

Phlogopite from Terezia quarry was described by Rumpf (1874) who called it "*Magnesiaglimmer*"; later it was studied by Tschermak (1879), Jacob (1938) and Kissling (1967). Platy crystals reaching up to 10 cm, frequently form monomineralic aggregates and banded textures, which were interpreted by Kissling (1967) as Liesegang-type patterns. Chemical data refinement of Terezia quarry phlogopites revealed prevailing hydroxyphlogopite with up to 11.92 mol% fluorphlogopite and significant contents of annite–siderophyllite (up to 23.51 mol%) together with minor amounts of manganophyllite (up to 1.71 mol%). X-ray powder diffraction data suggest that the Terezia phlogopite is a $2M_1$ polytype (Ilinca *et al.*, 1993).

Fibrous chrysotile is typically developed along the (001) cleavage planes in phlogopite and tends to form centripetal replacement zones resulting in the "chromatic zoning" described by Kissling (1967).

Palygorskite was identified by Kissling (1967) cavities of the coarse-grained dolomite. It overcoats scalenohedral calcite, suggesting deposition under low temperatures conditions. Palygorskite displays unusually large fibres of up to 1 cm in length.

2.12 Field stop 12 – The skarn deposit at Ocna de Fier. Iuliana quarry

Coordinates: 45°19'50.81"N – 21°44'54.76"E, Elevation 383 m

The quarry is located on the west slope of Ezeriş-Cârnecea syncline, south of Ocna de Fier. It is one of the largest mining works ever opened in the area (Fig. 42). Metasomatic zoning around a porphyritic granodiorite dyke can be observed on the eastern wall: andradite – tremolite – coarse-grained dolomite.

Fig. 42. Tremolite and hematite-rich area in Iuliana quarry, Ocna de Fier.

Nice specimens of hematite, magnetite, garnets and tremolite as well as ludwigite can easily be collected from the quarry. Unusual pseudomorphs of dolomite after octahedral magnetite, and of magnetite after andradite, have been described here. Most of the renowned "iron roses" of hematite originate in this place. Andradite usually displays cubic-trapesohedral {112} and rhombic-dodecahedral {110} crystals. "Incised" faces, due to adventive {112} forms superposed on {110} are frequent.

Tremolite is quite abundant and reaches unusual crystal sizes (up to 30 cm along *c* axis). It forms radiating or fan-like aggregates, commonly pseudomorphs after diopside. Old wet chemical analyses quoted by Kissling (1967) indicated a Fe-tremolite with 9.1 mol% ferroactinolite in solid solution.

Ludwigite occurs in a limited area on the eastern wall of the quarry close to the limit between skarns and dolomitic marble. The *locus typicus* for this mineral is the Magnet quarry, which is inaccessible now, but ludwigite from the Iuliana quarry shows remarkable similarities to the original material described by Tschermak (1874).

Detailed analytical data on ludwigites from both *loci* were published by Marincea (1999). The mineral occurs in the boron-bearing magnesian skarns, in a restricted association that includes calcite, forsterite (with 0.92–2.60% fayalite and 0.75–1.26% tephroite), magnetite (with 18.48–46.37% magnesioferrite) and clinohumite. Ludwigite is compositionally variable, with vonsenite ranging from 4.41 to 14.27 mol%, minor azoproite: up to 0.1 mol% $(Mg,Fe^{2+})_2(Ti^{4+},Mg)(BO_3)O_2$, and less than 6.55 mol% $(Mg,Fe^{2+})_2Al(BO_3O_2)$ in solid solution, and with minor Sn, Sb, Cr, Ni, Co, Mn and Zn. The compositional data, combined with information on the experimental synthesis of borates, indicate a temperature of crystallization at 600-650 °C and oxygen fugacities of 10^{-18}–10^{-14} atm.

Day 4

2.13 Field stop 13 – The skarn occurrence in Ogaşul Crişenilor, Oraviţa

Coordinates: 45° 2'49.01"N – 21°43'57.66"E, Elevation 398 m

General remarks on the Oraviţa-Ciclova area. Crystalline schists of the Bocşa Nappe occur in the western most part of the region (Coşoviţa Hill) (Fig. 43). Micaceous gneisses and amphibolites of the Bocşiţa Drimoxa formation (Bocşa Nappe, Supragetic unit) are unconformably overlain by a thin layer of limestones which is largely similar to the ridge-type sequence from Ocna de Fier – Dognecea. Grandite skarns and calc-silicate hornfels are banded parallel to the contact between the crystalline schists and the marbles. With the exception of several small apophyses of fine-grained granodiorites, the pluton responsible for this western thermal aureole does not crop out.

More significant contact metamorphism occurs east of Bocşa Nappe, where banatites penetrated a thick carbonate rock sequence belonging to the sedimentary cover of the Getic unit. As compared to the Ocna de Fier occurrence, the more diversified composition of the sedimentary paleosome (pure or cherty limestones, argillaceous limestones and marls), was the primary factor behind the skarn mineralogy which includes abundant Al- and Mg-rich calc-silicates. Several major banatitic bodies crop out in the area. They consist of early diorites, monzodiorites and isolated gabbros (Oraviţa Valley and Ciclova), and subsequent porphyritic granodiorites (Maidan and Tâlva Mică, north of Oraviţa Valley). Members of an ending sequence with dyke rocks (lamprophyres, andesites, syenites, alkali-granites, rhyolites and dacites) are randomly distributed throughout the main igneous bodies and the sedimentary formations. The diorite-gabbro banatites from Oraviţa Valley and Ciclova correlate well with products of the $B_{3.1}$ phase, whereas the north granodiorite intrusions are geochemically similar to the rocks of $B_{3.2}$ phase (Table 1; Russo-Săndulescu *et al.*, 1986c). Extensive hydrothermal alteration and related copper-dominant mineralization were recognized to accompany the banatitic intrusions.

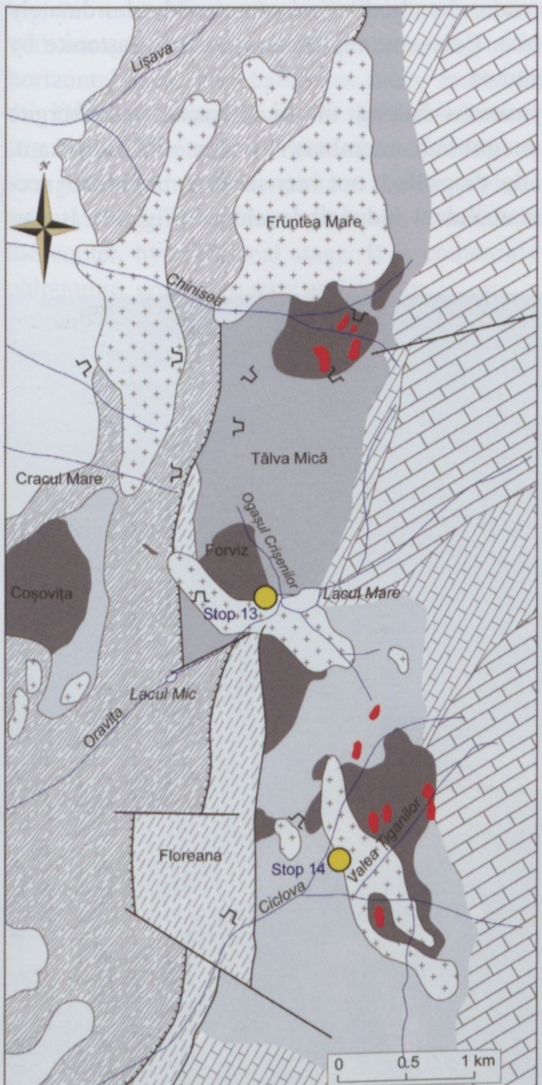


Fig. 43. Geological sketch of Oraviţa – Ciclova area (modified after Năstăseanu *et al.*, 1975). 1) Precambrian (micaceous gneisses, chlorite-muscovite schists, amphibolites, quartzites, metagabbros); 2) Permian (sandstones, argillic schists); 3) Oxfordian-Tithonian (limestones, marls); 4) Berriasian-Aptian (limestones, marls, argillaceous limestones); 5) Upper Cretaceous – Paleocene: plutonic banatites (granodiorites, diorites, monzodiorites); 6) Dykes (andesites, syenites, alkali granites, rhyolites, dacites, lamprophyres); 7) a. Hornfels, recrystallized limestones, b. Skarns; 8) Pleistocene (alluvial deposits); 9) Old mining works.

More than 120 minerals were described at Oraviţa-Ciclova (see Appendix 1), with one case of type locality: hörnesite. Csiklovaite is another material firstly described at Ciclova and for some years quoted in relation with a type locality status (Koch, 1948). Though proved to represent a mixture of tetradymite and bismuthinite (Bayliss, 1991) and officially discredited, csiklovaite is still included in the IMA list of minerals (2009). Ilinca *et al.* (1993) published

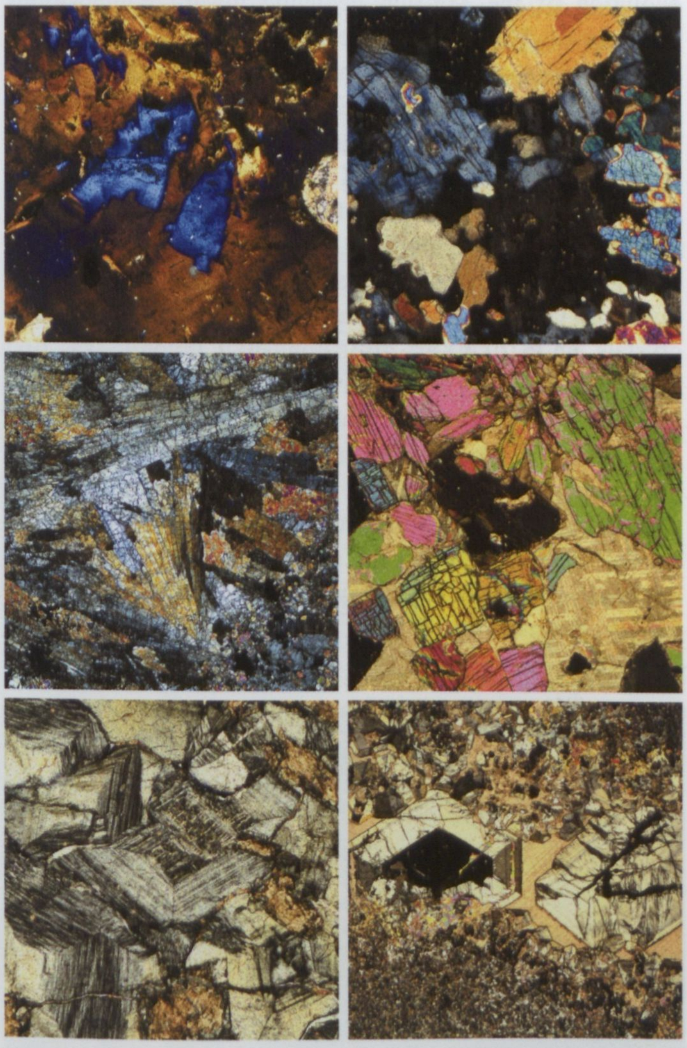


Fig. 44. Selected microphotographs of skarns minerals from Oraviţa-Ciclova (from above, left to right): vesuvianite (Ţiganilor Valley); gehlenite and diopside (Ogaşul Crişenilor); wollastonite (Chinisea Valley); diopside (Ţiganilor Valley); anisotropic garnets from Oraviţa and Ciclova, respectively. (Crossed polarizers, height of images approx. 5 mm).

a historical list of minerals described at Oraviţa Ciclova. The skarn deposit includes remarkable occurrences of high-temperature skarn minerals (gehlenite, Constantinescu *et al.*, 1998; Katona *et al.*, 2003), vesuvianite, wollastonite, garnets, scheelite; Fig. 44) and a rich assemblage of Bi sulphosalts including proudite, lillianite homologues, felbertalite, bismuthinite derivatives, cannizzarite, makovickyite–cupromakovickyite, kupčíkite, emplectite, junoite, cosalite and various tellurides and sulphotellurides (Ilinca, 1998).

The skarn occurrence. The Lacul Mare-Ogaşul Crişenilor area represents the "hottest" thermal metamorphic and metasomatic point in Banat. Monomineralic Mg-rich gehlenite (~$Gh_{50}Ak_{46}Na\text{-}mel_4$) skarns occur along the contact of a diorite intrusion (Katona *et al.*, 2003). Gehlenite is associated with diopside, granditic garnet, monticellite, and seldom with areas of magnetite exsolution of magnetite in the core zone of melilite grains. Monticellite, spurrite (or tilleyite, afwillite, kilchoanite) and garnet, occur during the retrograde evolution of the Mg-rich gehlenite toward compositions richer in Al. The retrograde reactions end up with complete transformation of gehlenite into vesuvianite and clintonite. These local modifications are interpreted as nearly closed-system (except for Na and Fe) retrograde reactions at moderate temperature (500–600 °C), controlled by the localized presence of small amounts of fluid at low pressure (*op. cit.)*. Gehlenite may incidentally be found as millimetric grains of dark green colour, within a groundmass of diopside and clay minerals. Garnets, vesuvianite and clintonite (green, platy crystals, up to 2 cm) are also abundant. Clintonite was first described here by Popescu & Constantinescu (1977). Previous authors might not have failed to notice this occurrence, but most probably the mineral was considered phlogopite. Minor amounts are also known from some old waste dumps, north of Oraviţa (*e.g.* the Clementi gallery).

The late hydrothermal stages produced significant amounts of epidote, calcite, quartz, K-feldspar and zeolites (stilbite, thomsonite).

Fig. 45. Weathered monzodiorite exposure in Ţiganilor Valley, Ciclova.

2.14 Field stop 14 – The skarns and banatites in Ţiganilor Valley, Ciclova

Coordinates: 45° 1'39.50"N – 21°44'22.72"E, Elevation 335 m

In the north-eastern part of Ciclova, calc-magnesian skarns with wollastonite, diopside, chondrodite, grandite, vesuvianite and minor phlogopite, are largely exposed along contacts of a monzodiorite-diorite banatitic body (Figs. 45 and 46) with Lower to Middle Cretaceous argillaceous-carbonate rocks. Skarns assemblages show strong disequilibria with scarce or no paragenetically intergrown phases.

Wollastonite forms large, prismatic or needle-shaped crystals sometimes in monomineralic concentrations. It is associated with diopside, chondrodite and garnet, and subordinately with vesuvianite. Extensive replacements of wollastonite by calcite are common.

Calcic pyroxenes belong to the diopside–hedenbergite series, but magnesian members are by far dominant. Macroscopically, diopside is not very striking, but in thin sections it is quite abundant and well developed (Fig. 44). It usu-

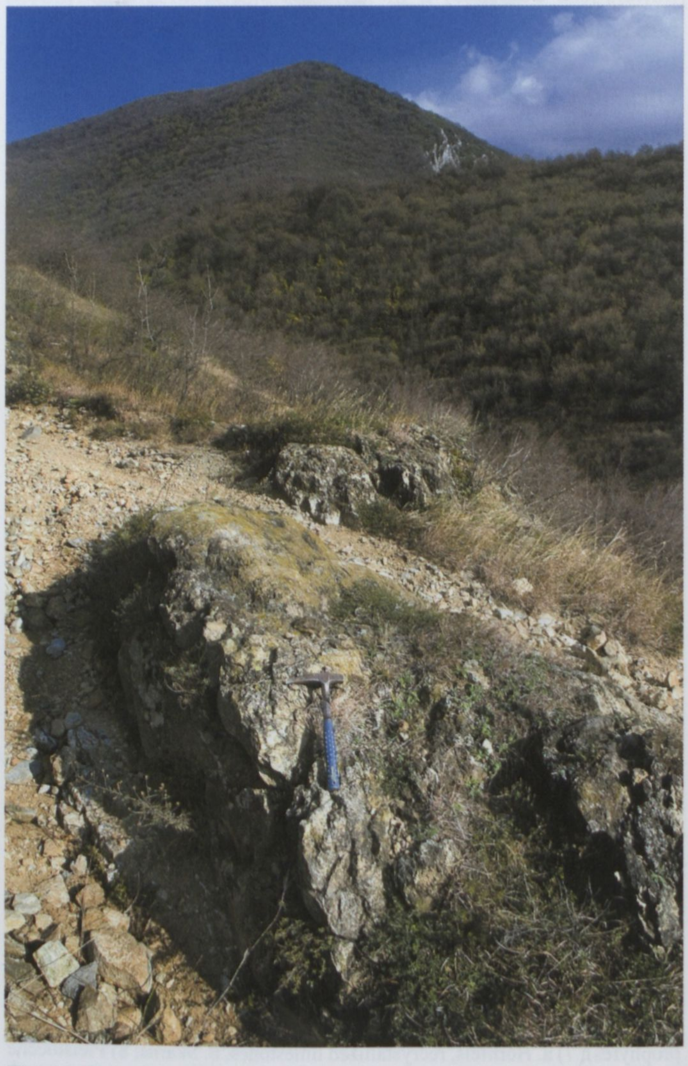


Fig. 46. Skarns outcrops on the northern slope of Ţiganilor Valley, Ciclova.

ally replaces wollastonite, and is in its turn substituted by garnet and vesuvianite. Retrograde hydrothermal metamorphism of diopside resulted in calcite and quartz.

Two generations of garnet of significant chemical contrast occur in Ţiganilor Valley: one with Al-rich composition, forming euhedral, anomalous anisotropic crystals, and another represented by isotropic andradite which frequently cuts and replace the grossular-dominant members. Locally, some odd myrmekitic intergrowths between andradite and K-feldspar are accessible to microscopic observation.

Vesuvianite is the most abundant skarn mineral. Ţiganilor Valley is in fact, the most spectacular occurrence of this mineral in Romania. It appears as minute, yellowish-green prismatic crystals or compact, brownish masses. The most striking, yet not so frequent, are the huge, pegmatite-like crystals with tetragonal-bipyramidal habit, reaching up to 10 cm along horizontal axes. This habit was found to be characteristic to the Oraviţa-Ciclova zone, as the other known occurrences (*e.g.* Sasca Montană – Constantinescu, 1980) display mainly tetragonal prisms. Vesuvianite is the latest phase in the skarn mineral sequence and most probably, it makes the transition to the cooler, hydrothermal stage. It is commonly replaced by phlogopite, epidote, quartz and calcite.

Isolated specimens from the aureoles of several vein bodies of syenites, exhibit unusual fibrous-radial aggregates of vesuvianite, apparently pseudomorph after a fibre-shaped mineral. X-ray powder diagrams of such samples pointed to major vesuvianite and traces of serpentine and szaibélyite (Constantinescu *et al.*, 1988b).

Ţiganilor Valley is the second major occurrence in Romania, of a high-temperature clinopyroxene with extremely high Al and Fe^{3+} contents (Pascal *et al.*, 2005). The occurrence is located at the contact between marble (now exoskarn) and diorite (now endoskarn) and it is strikingly similar to the one described by the same authors in Cornet Hill (Field stop 3). The compositional range of the pyroxene is 0.40 to 0.63 ^{IV}Al *apfu*, compared with 0.30-0.72 in Valea Cerboaia and 0.30-0.72 in Cornet Hill.

2.15 Field stop 15 – The porphyry copper ore deposit at Suvorov, Moldova Nouă

Coordinates: 44°44'28.37"N – 21°42'7.07"E, Elevation 289 m

The Suvorov porphyry copper ore deposit belongs to the southern most segment of the BMMB in Romania, characterized by N–S hypabyssal granodiorite and quartz diorite bodies with eastern vergence (Vlad, 1983). Surrounding sedimentary formations are represented by a comprehensive Jurassic sequence, dominated by Oxfordian–Tithonian limestones, and by Lower Cretaceous (Berriasian–Aptian) limestones and marls (Gheorghiţă, 1975) (Fig. 47). Contact metamorphism around banatitic bodies is extensive: recrystallized limestones, biotite-andalusite-actinolite or diopside-biotite hornfels, garnet-diopside-vesuvianite and diopside-plagioclase endoskarns, wollastonite-garnet-pyroxene-chondrodite exoskarns, *etc.*

High-temperature, pervasive potassic hydrothermal alteration developed in the main granodiorite body, in Suvorov Valley. According to Vlad (1983) it may be ascribed to the "deuteric" late-magmatic domain and consists of biotite, orthoclase, quartz and apatite, either as veinlets or as global substitutions of the magmatic rock groundmass. Subsequent alteration is represented by chlorite developed on biotite, and a second generation of biotite developed on amphiboles. The potassic background is overlapped by phyllic alteration with quartz and illite ("sericite"), with subordinate amounts of chlorite. Local areas of intense silicification are widespread. Peripheral skarn aureoles are affected by propylitic alteration with epidote, chlorite and calcite. The three alteration types are amenable to the Lowell and Guilbert concentric model of porphyry copper hydrothermal alteration.

The mineralization consists of chalcopyrite, pyrite, magnetite with minor molybdenite, sphalerite and tetrahedrite and is differentiated against the host hydrothermal alteration. Potassic areas are associated with magnetite impregnations and subordinate chalcopyrite and pyrite. Propylitic alteration contains mainly magnetite disseminations with traces of chalcopyrite and pyrite. Phyllic areas are dominated by mineralized

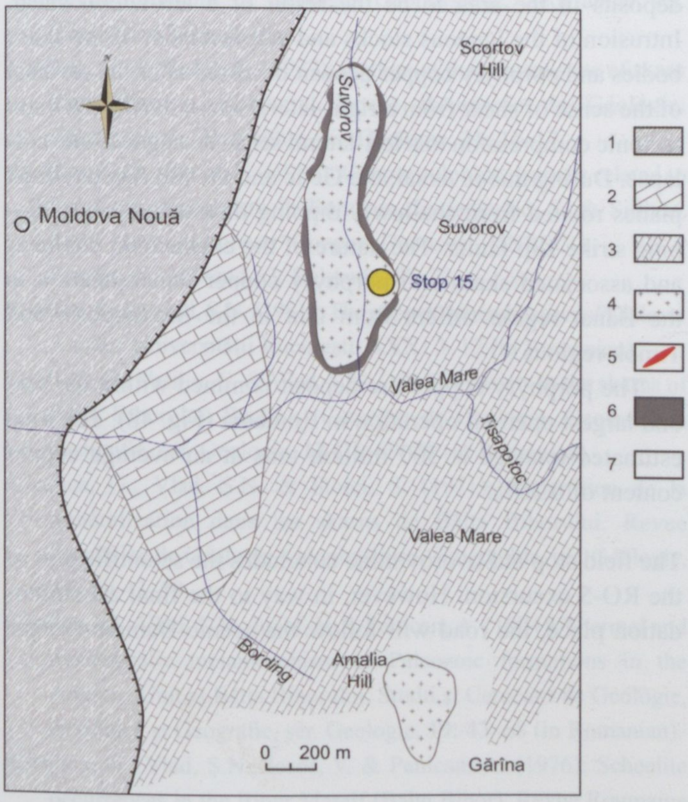


Fig. 47. Geological map of Suvorov area, Moldova Nouă (redrawn after Gheorghiţă, 1975). 1) Crystalline schists (Bocşa Nappe, Supragetic unit); 2) Jurassic (detrital formations, limestones, marls); 3) Berriasian-Aptian (limestones, marls); 4) Upper Cretaceous – Paleocene: banatites (porphyritic granodiorites); 5) skarns; 6) Pleistocene (alluvial deposits).

Fig. 48. Panorama view of the porphyry-copper open pit at Suvorov, Moldova Nouă.

veinlets with pyrite, chalcopyrite ± sphalerite, molybdenite or pyrite ± tetrahedrite, with the later surrounded by impregnations of pyrite and chalcopyrite.

The upper parts of the porphyry complex host supergene transformation areas of up to 5-10 m thick, with kaolinite, illite, montmorillonite, copper carbonates and sulphates. Such environments provided the type locality for cyanotrichite $Cu_4Al_2[(OH)_{12}|SO_4]\cdot 2H_2O$.

Drew (2005) interprets the map patterns associated with the skarn bodies, granitoid stocks, and porphyry copper deposits in the area to be the result of a left-lateral shear. Intrusion of the igneous stocks and emplacement of the skarn bodies and porphyry copper deposit occurred after the reversal of the sense of shear from a right-lateral sense during the main tectonic compression to a left-lateral sense during tectonic collapse. During this reversal, the Getic and the Supragetic thrust planes rotated from shallowly dipping thrusts to steeply dipping strike-slip faults. The nature of the extensional duplexes and associated skarn and porphyry copper mineralization in the Banat region differs from that in the Srednogorie and Timok regions.

The porphyry copper ore deposit is mined within the second largest open pit operation in Romania (Fig. 48). The total estimated tonnage is 500 million tons at an average copper content of 0.35%.

The field stop at Suvorov mine concludes the scientific part of the RO-5 excursion. However, in way to the final accommodation place, the road will follow the scenic Danube Gorges (Fig. 49) and will offer a complete transect of the Southern Carpathians.

Acknowledgements

The author is specially indebted to C. Ionescu, V. Hoeck, F. Koller, G. Papp, D. Pop, T. Weiszburg and D. Topa for their kind support, understanding and infinite patience. Thanks are due to Mrs. M.R. Cîmpean and Mr. D. Ardelean for kindly helping in the preparation of the visit at Baita mine, to Mr. Iacob Chişărău for supporting the visit to Moldova Nouă open pit and to Mr. Gehrig Schultz and Mr. Dorin Dordea from "Prospecţiuni" S.A. for generously providing the terrain vehicles.

Fig. 49. The Danube Gorges.

References

Andrei, J., Cristescu, T., Calotă, C., Proca, A., Romanescu, D., Russo-Săndulescu, D., Ştefan, A., Suceavă, M., Bradu, M., Hannich, D. & Albaiu, M. (1989): Spatial distribution and structural images of banatites from Romania deduced from gravity and magnetic data. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géophysique, **33**: 79–85.

Barton, P.B. & Bethke, P.M. (1987): Chalcopyrite disease in sphalerite: Pathology and epidemiology. American Mineralogist, **72**: 451–467.

Bayliss, P. (1991): Crystal chemistry and crystallography of some minerals in the tetradymite group. American Mineralogist, **76**: 257–265.

Bente, K. & Doering, T. (1993): Solid-state diffusion in sphalerites: an experimental verification of the "chalcopyrite disease". European Journal of Mineralogy, **5**: 465–478.

Berza, T., Balintoni, I., Iancu, V., Seghedi, A. & Hann, H.P. (1994): Southern Carpathians. In Berza, T. (ed.): ALCAPA II Field Guidebook; Southern Carpathians and Apuseni Mountains, Romania. Romanian Journal of Tectonics and Regional Geology, **75** (Suppl. 2): 37–49.

Berza, T., Constantinescu, E. & Vlad, Ş.N. (1998): Upper Cretaceous magmatic series and associated mineralization in the Carpathian–Balkan Orogen. Resource Geology, **48**: 291–306.

Bleahu, M. (1976): Structural position of the Apuseni Mountains in the Alpine System. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **20**: 7–19.

Bleahu, M., Bordea, J., Matea, Gh., Cioflica, G., Ştefan, A., Popescu, A., Marinescu, F. & Bordea, S. (1985): Geological map of Romania, scale 1:50,000, Pietroasa sheet. Bucharest: Institute of Geology and Geophysics.

Boccaletti, M., Manetti, P. & Peccerillo, A. (1974): The Balkanids as an instance of back-arc thrust belt: possible relation with the Hellenids. Geological Society of America Bulletin, **85**: 1077–1084.

Boccaletti, M., Manetti, P., Peccerillo, A. & Stanisheva-Vasilieva, G. (1978): Late Cretaceous high potassium volcanism in eastern Srednogorie, Bulgaria. Geological Society of America Bulletin, **89**: 439–447.

Bojar, A.V., Neubauer, F. & Fritz, H. (1998): Cretaceous to Cenozoic thermal evolution of the south-western Southern Carpathians: evidence from fission-track thermochronology. Tectonophysics, **297**: 229–249.

Bonev, I.K., Vassileva, R.D., Zotov, N. & Kouzmanov, K. (2005): Manganilvaite, $CaFe^{2+}Fe^{3+}(Mn, Fe^{2+})(Si_2O_7)O(OH)$, a new mineral of the ilvaite group from Pb-Zn skarn deposits in the Rhodope Mountains, Bulgaria. Canadian Mineralogist, **43**: 1027–1042.

Born, I. von (1774): Briefe über mineralogische Gegenstände, auf seiner Reise durch das Temeswarer Bannat, Siebenbürgen, Ober- und Nieder-Hungarn, (…) geschrieben. Frankfurt -Leipzig, 228 p.

Burt, D.M. (1982): Skarn deposits – historical bibliography through 1970. Economic Geology, **77**: 755–763.

Ciobanu, C.L. & Cook, N.J. (2000): Intergrowths of bismuth sulphosalts from the Ocna de Fier Fe-skarn deposit, Banat, Southwest Romania. European Journal of Mineralogy, **12**: 899–917.

Ciobanu, C.L., Cook, N.J. & Stein, H. (2002): Regional setting and geochronology of the Late Cretaceous Banatitic Magmatic and Metallogenetic Belt. Mineralium Deposita, **37**: 541–567.

Ciobanu, C.L., Pring, A. & Cook, N.J. (2004): Micron- to nano-scale intergrowths among members of the cuprobismutite series and paděraite: HRTEM and microanalytical evidence. Mineralogical Magazine , **68** (2): 279–300.

Cioflica, G. & Vlad, Ş.N. (1968): Observations on the skarns from Băiţa Bihorului. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **13**: 43–50 (in Romanian).

Cioflica, G. & Vlad, Ş.N. (1970): La nature polyascendante des métasomatites laramiques de Băiţa Bihorului (Monts Apuseni). Acta Geologica Academiae Scientiarum Hungaricae, **14**: 135–141.

Cioflica, G. & Vlad, Ş.N. (1973a) Aikinite in the skarns of Băiţa Bihorului. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **18** (2): 311–316 (in Romanian).

Cioflica, G. & Vlad, Ş.N. (1973b): The correlation of the Laramian metallogenic events belonging to the Carpathian – Balkan area. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **17**: 217–214.

Cioflica, G. & Vlad, Ţ.N. (1973c) Contribution ŕ la connaissance des types structuraux de pyrométasomatites laramiens de Roumanie. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **17** (1): 3–14.

Cioflica, G. & Vlad, Ş.N. (1977): Outline of the present state of skarn knowledge in Romania. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **21**: 11–17.

Cioflica, G. & Vlad, Ş.N. (1980): Copper sulphide deposits related to Laramian magmatism in Romania. In Janković, S. & Sillitoe, R.H. (eds): European Copper Deposits, UNESCO – IGCP Projects N° 169 and 63, Belgrade, 67–71.

Cioflica, G. & Vlad, Ş.N. (1981): The copper mineralization of Ciclova. Analele Universităţii Bucureşti, **XXX**: 3–17 (in Romanian).

Cioflica, G., Vasiliu, C. & Vlad, Ş.N. (1967): Garnets in the skarns of Băiţa Bihorului. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **12** (1): 69–79 (in Romanian).

Cioflica, G., Vlad, Ş.N. & Stoici, S. (1971): Repartition de la minéralization dans les skarns de Băiţa Bihorului. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **15** (1): 43–58.

Cioflica, G., Vlad, Ş.N., Iosof, V. & Panican, A. (1974): Thermal and metasomatic metamorphism of Paleozoic formations in the Arieşeni Unit at Băiţa Bihorului. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **19**: 43–68 (in Romanian).

Cioflica, G., Vlad, Ş.N., Iosof, V. & Panican, A. (1976): Scheelite occurrences in the Bihor Massif (Băiţa Bihor). Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **20** (2): 169–177.

Cioflica, G., Vlad, Ş.N., Volanschi, E. & Stoici, S. (1977): Magnesian skarns and associated mineralization from Băiţa

Bihorului. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **22**: 39–57 (in Romanian).

Cioflica, G., Istrate, G., Ştefan, A. & Vlad, Ş.N. (1980): Contact metamorphism related to Laramian magmatism in Romania. Proceedings of the XIth Congress of Carpatho–BalkanGeological Association, Magmatism and Metasomatism, Kiev, 204–210.

Cioflica, G., Berbeleac, I., Lazăr, C., Ştefan, A. & Vlad, Ş.N. (1982): Metallogeny related to Laramian magmatism in the Bihor Mts. (Northern Carpathians – Romania). Analele Universităţii Bucureşti, **31**: 3–12.

Cioflica, G., Jude, R., Lupulescu, M. & Udrescu, C. (1991): The banatitic magmatites of the Lilieci–Liubcova area (Banat), Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **35**: 3–22.

Cioflica, G., Jude, R. & Lupulescu, M. (1992): Cupriferous metallization processes associated with Upper Cretaceous–Eocene magmatites from Romania. Romanian Journal of Mineralogy, **76**: 1–16.

Cioflica G., Jude, R. & Lupulescu, M. (1993): Banatitic magmatites in Lăpuşnicul Mare area (Banat). Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **38**: 3–22 (in Romanian).

Cioflica, G., Pécskay, Z., Jude, R. & Lupulescu, M. (1994): K-Ar ages of Alpine granitoids in the Hăuzeşti–Drinova area (Poiana Ruscăi Mountains, Romania). Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **38**: 3–8.

Cioflica, G., Jude, R., Lupulescu, M., Şimon, Gr. & Damian, Gh. (1995): New data on the Bi-minerals from the mineralization related to Paleocene magmatites in Romania. Romanian Journal of Mineralogy, **76**: 9–23.

Cioflica, G., Jude, R., Lupulescu, M. & Ducea, M. (1996): Lower crustal origin of the Late Cretaceous–Eocene arc magmatism in the western part of the Southern Carpathians, Romania. In Knežević, V. & Krstić, B. (eds): Terranes of Serbia. University of Belgrade, 103–107.

Cioflica, G., Jude, R. & Lupulescu, M. (1997): Late Cretaceous–Eocene arc magmatism related porphyry-type deposits in Romania. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **41**: 3–18.

Codarcea, Al. (1931): Geologic and petrographic study of Ocna de Fier – Bocşa Montană (Caraş county, Banat). Anuarul Institutului Geologic al României, **15**: 424 p (in Romanian).

Constantinescu, E. (1970): Idocrase des skarns de Sasca Montană (Banat). Analele Universităţii Bucureşti, **19**: 43–45.

Constantinescu, E. (1977): Mineralogy and petrology of Laramian magmatites between Nera Valley and Radimniuţa Valley. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **22**: 87–102 (in Romanian).

Constantinescu E. (1980): Mineralogy and genesis of the skarn deposit at Sasca Montană. Bucharest: Editura Academiei, 158 p (in Romanian).

Constantinescu, E., Ilinca, Gh. & Ilinca, A. (1988a) Laramian hydrothermal alteration and ore deposition in the Oraviţa – Ciclova area. South-western Banat. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **72–73** (2): 13–26.

Constantinescu, E., Ilinca, Gh. & Ilinca, A. (1988b) Contributions to the study of the Oraviţa – Ciclova skarn occurrence, south-western Banat. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **72–73** (2): 27–45.

Constantinof, D. (1979): The banatitic complex of Oraviţa – Ciclova (Banat). PhD Thesis, University of Bucharest, 177 p.

Cook, N.J. & Ciobanu, C.L. (2001): Paragenesis of Cu-Fe ores from Ocna de Fier–Dognecea (Romania), typifying fluid plume mineralization in a proximal skarn setting. Mineralogical Magazine, **65**: 351–372.

Cotta, B. von (1864): Erzlagerstätten im Banat und in Serbien. Wien: Braumüller, 108 p.

Dabovski, C., Harkovska, A., Kamenov, B., Mavrudchiev, B., Stanisheva-Vassileva, G. & Yanev, Y. (1991): A geodynamic model of the Alpine magmatism in Bulgaria. Geologica Balcanica, **21**: 3–15.

Degău, I. (2007): The Beiuş Depression: aspects of traditional economic life. cumpana.wordpress.com (in Romanian).

Djordjević, M., Banjesević, M., Ralević, B & Milicić, M. (1997): Mesozoic magmatism of Djerdap Area. In Grubić, A. & Berza, T. (eds): Geology of Djerdap Area, 121–128.

Downes, H., Seghedi, I., Szakacs, A., Dobosi, G., James, D.E., Vaselli, O., Rigby, I.J., Ingram, G.A., Rex, D. & Pécskay, Z. (1995a): Petrology and geochemistry of late Tertiary/Quaternary mafic alkaline volcanism in Romania. Lithos, **35**: 65–81.

Downes, H., Vaselli, O., Seghedi, I., Ingram, G., Rex, D., Coradossi, N., Pécskay, Z. & Pinarelli, L. (1995b): Geochemistry of late Cretaceous–early Tertiary magmatism in Poiana Ruscă (Romania). Acta Vulcanologica, **7**: 209–217.

Drew, L.J. (2005): A tectonic model for the spatial occurrence of porphyry copper and polymetallic vein deposits – Applications to Central Europe. USGS Scientific Investigations Report 2005–5272, 43 p.

Dupont, A., Vander Auwera, J., Pin, C., Marincea. Şt. & Berza, T. (2002): Trace element and isotope (Sr, Nd) geochemistry of porphyry and skarn-mineralising Late Cretaceous intrusions from Banat, western Southern Carpathians, Romania. Mineralium Deposita, **37**: 568–586.

Ehrler, J.J. (1774): Das Banat vom Ursprung bis Jetzo. [A history of Banat from its origins to our days. Published in Romanian in 1982 as "Banatul de la origini până acum (1774)", transl. C. Feneşan. Timişoara: Editura Facla, 298 p].

Gheorghiţă, I. (1975): Mineralogical and petrographical study of Moldova Nouă region (Suvorov–Valea Mare zone). Studii Tehnice şi Economice Inst. Geol. Geof., **11** (1): 188 p (in Romanian).

Gheorghiţescu, D. (1972): Skarn mineralogy and cupriferous mineralisation at Vărad. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **17**: 49–66 (in Romanian).

Gheorghiţescu, D. (1975): Mineralogical and geochemical study of thermal and metasomatic contact areas from Oraviţa (Coşoviţa). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **61** (1): 59–103 (in Romanian).

Giuşcă, D. (1950): Le massif eruptif de la Vlădeasa. Anuarul Comitetului Gologic al României, **28**: 1–53.

Giuşcă, D. (1974): Petrology of endogenous rocks. Bucharest: Editura Tehnică, 475 p (in Romanian).

Giuşcă, D., Cioflica, G. & Savu, H. (1965): Les caractčres chimiques des roches de la province banatitique. The VIII[th] Congress of the Carpatho-Balkan Geological Association, Reports III, Part II. Sofia, 291–296.

Giuşcă, D., Cioflica, G. & Savu, H. (1966): Petrological characterization of the Banatitic Province. Anuarul Comitetului de Stat al Geologiei, **35**: 13–45 (in Romanian).

Griselini, F. (1780): Versuch einer politischen and natürlichen Geschichte des Temeswarer Banats, in Briefen an Standenpersonen und Gelehrte. Wien: Krauss. [Published in Romanian in 1982 as "Încercare de istorie politică şi naturală a Banatului Timişoarei". Timişoara: Editura Facla, 336 p.].

Gunnesch, K., Gunnesch M., Seghedi I. & Popescu C. (1975): Contributions to the study of the banatitic rocks in Liubcova – Lăpuşnicu Mare zone (west part of Almăj Mts. and south-west part of Semenic Mts.) Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **61** (1): 169–189 (in Romanian).

Gunnesch, K., Gunnesch, M. & Vlad, C. (1978): Petrographical and petrochemical considerations on the banatites from Teregova-Lăpuşnicel zone (Semenic Mts. zone). Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **23**: 239–248 (in Romanian).

Heinrich, C.A. & Neubauer, F. (2002): Cu – Au – Pb – Zn – Ag metallogeny of the Alpine – Balkan – Carpathian – Dinaride geodynamic province. Mineralium Deposita, **37**: 533–540.

Hoeck, V., Ionescu, C., Balintoni, I. & Koller, F. (2009): The Eastern Carpathians "ophiolites": Remnants of a Triassic ocean. Lithos, **108**: 151–171.

Iancu, V. (1986): Unites structurales supragétiques et infragétiques de la partie ouest des Carpathes Méridionales. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **70–71(5)**: 109–127.

Ilinca, G. (1998): Crystal chemistry of bismuth sulphosalts from the Banatitic province. PhD Thesis, University of Bucharest, Romania, 356 p (in Romanian).

Ilinca, G. (2006): Rare sulphosalt minerals in Romania. Acta Mineralogica-Petrographica (Szeged), Abstract Series, **5**: 42–46.

Ilinca, G. & Makovicky, E. (1999): Chemical characterisation and paragenesis of nuffieldite from Valea Seacă, Bihor Mts., Romania. Romanian Journal of Mineralogy, **79** (1): 40 (abstr.).

Ilinca, Gh., Marincea, Şt., Iancu, V., Russo-Săndulescu, D. & Seghedi, I. (1993): Mineral occurrences in Southwestern Banat, Romania. Romanian Journal of Mineralogy, **76** (Suppl. 2): 38 p.

Ilinca, G., Vizitiu, Al., Topa, D. & Vlad, Ş.N. (2006): A new occurrence of manganilvaite $CaFe^{2+}Fe^{3+}(Mn^{2+}, Fe^{2+})[Si_2O_7]O(OH)$ at Dognecea, south-western Banat, Romania: chemical composition, crystal structure and cation ordering. Acta Mineralogica-Petrographica (Szeged), Abstract Series, **5**: 47.

Întorsureanu, I. (1986): Banatitic eruptive rocks in the Bozovici–Liubcova zone (Banat), Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **70**: 53–67.

Ionescu, C. (1996a) The metallogenetic study of the banatitic massifs from Budureasa and Pietroasa (Bihor Mts.). Ph.D. Thesis, Babeş–Bolyai University, Cluj-Napoca, 180 p (in Romanian).

Ionescu, C. (1996b): Stage relations between the postmagmatic processes from the contact aureoles of the Budureasa and Pietroasa banatitic massifs (Bihor Mts.). Studia Universitatis Babeş–Bolyai, Geologia, **41** (1): 127–135.

Ionescu, C. & Balaban, A. (1998): Thermal contact aureola of the banatitic intrusions from Budureasa and Pietroasa, Bihor Mts. Studia Universitatis Babeş–Bolyai, **43** (1): 67–74 (in Romanian).

Ionescu, C. & Hoeck, V. (2005): Brucite deposits in the Apuseni Mts. (Romania). Mineralia Slovaca, **37** (3): 358–360.

Ionescu, C. & Hoeck, V. (2010): Mesozoic ophiolites and granitoids in the Apuseni Mountains. RO2 Field trip guide, IMA–2010 Budapest. Acta Mineralogica-Petrographica (Szeged), Field Guide Series, **20**: 1–45.

Ionescu, C., Hoeck, V., Tămaş, C. & Balica, C. (2009): MAEGS-16 Field trip guide: Geology of the Apuseni Mountains (Romania). Cluj-Napoca: Presa Universitară Clujeană/Cluj University Press, 31 p.

Istrate, G. (1978): Petrologic study of the Vlădeasa Massif (western part). Anuarul Institutului de Geologie şi Geofizică, **53**: 177–298.

Istrate, G. & Udubaşa, G. (1981): Contributions to the metallogenic knowledge of Budureasa banatitic massif (Apuseni Mts.). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **65**: 5–19 (in Romanian).

Istrate, G., Ştefan, A. & Medeşan, A. (1978): Spurrite and tilleyite in the Cornet Hill, Apuseni Mountains, Romania. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **22**: 143–153.

Jacob, J. (1938): Magnesiaglimmer von Moravicza. Schweizerische Mineralogische und Petrographische Mitteilungen, **18**: 473–474.

Janković, S. (1990): Types of copper deposits related to volcanic environment in the Bor district, Yugoslavia. Geologische Rundschau, **79**: 467–478.

Janković, S. & Jelenković, R. (1997): Correlation between the Oraviţa-Krepoljin and the Bor–Srednogorie metallogenic zones. Romanian Journal of Mineral Deposits, **78**: 57–70.

Katona, I., Pascal, M.-L., Fonteilles, M. & Verkaeren, J. (2003): The melilite (Gh_{50}) skarns of Oraviţa, Banat, Romania: Transition to gehlenite (Gh_{85}) and to vesuvianite. Canadian Mineralogist, **41**: 1255–1270.

Karamata, S., Knezević, V., Pécskay, Z. & Djordjević, M. (1997): Magmatism and metallogeny of the Ridanj–Krepoljin belt (eastern Serbia) and their correlation with northern and eastern analogues. Mineralium Deposita, **32**: 452–458.

Karamata, S., Dimitrijević, N.M. & Dimitrijević, D.M. (1999): Oceanic realms in the central part of the Balkan Peninsula during the Mesozoic. Slovak Geological Magazine, **5**: 173–177.

Kissling, Al. (1967): Mineralogical and petrological studies in the exoskarn zone at Ocna de Fier (Banat). Bucharest: Editura Academiei, 129 p (in Romanian).

Kissling, Al. (1971): Crystallographic study of diopside and apatite from Ocna de Fier. Studii şi Cercetări de Geologie, Geofizică şi Geografie, sér. Geologie, **16** (2): 515–519 (in Romanian).

Koch, S. (1948): Bismuth minerals in the Carpathian Basin. Acta Universitatis Szegediensis, Acta Mineralogica Petrographica, **2**: 1–23.

Kräutner, H.G., Vîjdea, E. & Romanescu O. (1986): K-Ar dating of the banatitic magmatites from the Southern Poiana Ruscă Mts. (Rusca Montană sedimentary basin). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **70–71** (1): 373–388.

Lazăr, C. & Întorsureanu, I. (1981): The iron ore deposit at Maşca – Băişoara (Apuseni Mts.). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **66** (2): 45–69 (in Romanian).

Marincea, Şt. (1993): Mineralogical data concerning the magnesian hornfels in the Pietroasa area (Bihor Mountains). Romanian Journal Mineralogy, **76**: 29–41.

Marincea, Şt. (1999): Ludwigite from the type locality, Ocna de Fier, Romania: New data and review. Canadian Mineralogist, **37**: 1343–1362.

Marincea, Şt. (2000a) Magnesian borates and associated minerals in the Cacova Ierii skarn deposit (Apuseni Mountains, Romania). Geonomos, **8**: 1–7.

Marincea, Şt. (2000b) The influence of Al on the physical and crystallographic properties of ludwigite in three Romanian occurrences. European Journal of Mineralogy, **12**: 809–823.

Marincea, Şt. (2000c) Fluoborite in magnesian skarns from Băiţa Bihor (Bihor Massif, Apuseni Mountains, Romania). Neues Jahrbuch für Mineralogie – Monatshefte, 357–371.

Marincea, Şt. (2001): New data on szaibélyite from the type locality, Băiţa Bihor, Romania. Canadian Mineralogist, **39**: 111–127.

Marincea, Şt. (2004): A contribution to the study of kotoite: data on three Romanian occurrences. Neues Jahrbuch für Mineralogie – Monatshefte, **6**: 253–274.

Marincea, Şt. (2006): Suanite in two boron-bearing magnesian skarns from Romania: data on a longtime ignored mineral species. Neues Jahrbuch für Mineralogie – Abhandlungen, **182**: 183–192.

Marincea, Şt. & Russo-Săndulescu, D. (1996): Prehnite in calcic endoskarns from Surduc: A look on a neglected mineral species in Romania. Romanian Journal of Mineralogy, **77**: 55–71.

Marincea, Şt., Bilal, E., Verkaeren, J., Pascal, M.-L. & Fonteilles, M. (2001): Superposed parageneses in the spurrite-, tilleyite and gehlenite-bearing skarns from Cornet Hill, Apuseni Mountains, Romania. Canadian Mineralogist, **39**: 1435–1453.

Mumme, W.G. & Žak, L. (1985): Paděraite, $Cu_{5.9}Ag_{1.3}Pb_{1.6}Bi_{11.2}S_{22}$, a new mineral of the cuprobismutite – hodrushite group. Neues Jahrbuch für Mineralogie Monattshefte, 557–567.

Năstăseanu, S., Constantinof, D., Orăşanu, T., Stancu, J. & Rogge-Ţăranu, E. (1975): Geological map of Romania, scale 1:50,000, Oraviţa sheet. Bucharest: Insitute of Geology and Geophysics.

Năstăseanu, S., Bercia, I., Iancu, V., Vlad, Ş.N. & Hîrtopanu, I. (1981): The structure of the Southern Carpathians (Mehedinţi–Banat Area). Guide to excursion B 2. Carpatho-Balkan Geological Association XII[th] Congress. Bucharest, 100 p.

Neubauer, F. (2002): Contrasting Late Cretaceous with Neogene ore provinces in the Alpine–Balkan–Carpathian–Dinaride collision belt. In Blundell, D., Neubauer, F. & von Quadt, A. (eds): The timing and location of major ore deposits in an evolving orogen. Geological Society (London) Special Publication **204**: 81–102.

Neubauer, F., Heinrich, C. & GEODE working group incl. Tomek, C., Lips, A., Nakov, R., Quadt, A. V., Peytcheva, I., Handler, R. Bonev, I., Ivăşcanu, P., Roşu, E., Ivanov, Z., Kaiser-Rohrmeier, M. *et al.* (2003): Late Cretaceous and Tertiary geodynamics and ore deposit evolution of the Alpine–Balkan–Carpathian–Dinaride orogen. In Eliopoulos, D. *et al.* (eds): Mineral exploration and sustainable development. Rotterdam: Millpress, 1133–1136.

Nicolescu, S. & Cornell, D.H. (1999): P–T conditions during skarn formation in the Ocna de Fier ore district, Romania. Mineralium Deposita **34**: 730–742.

Panaiotu, C. (1998): Paleomagnetic constraints on the geodynamic history of Romania. In Reports on geodesy. Monograph of Southern Carpathians. CEI CERGOP study group no. 8, Geotectonic analysis of the region of Central Europe. Warsaw Univ. of Technology – Institute of Geodesy and Geodetic Astronomy, **7 (37)**: 205–216.

Papp, G. (2004): History of minerals, rocks and fossil resins discovered in the Carpathian region. Studia Naturalia, **15**. Budapest: Magyar Természettudományi Múzeum, 215 p.

Pascal, M.-L., Fonteilles, M., Verkaeren, J., Piret, R. & Marincea, Şt. (2001): The melilite-bearing high-temperature skarns of the Apuseni Mountains, Carpathians, Romania. Canadian Mineralogist, **39**: 1405–1434.

Pascal, M.-L., Fonteilles, M., Katona, I. & Verkaeren, J. (2005): Relics of high-temperature clinopyroxene on the join Di–CaTs with up to 72 mol% $Ca(Al,Fe^{3+})AlSiO_6$ in the skarns of Ciclova and Măgureaua Vaţei, Carpathians, Romania. Canadian Mineralogist, **43**: 857–881.

Pătraşcu, S., Bleahu, M., Panaiotu, C. & Panaiotu, C.E. (1992): The paleomagnetism of the Upper Cretaceous magmatic rocks in the Banat area of Southern Carpathians: tectonic implications. Tectonophysics, **213**: 314–352.

Pătraşcu, St., Panaiotu, C., Şeclăman, M. & Panaiotu, C.E. (1994): Timing of rotational motion of Apuseni Mountains (Romania): paleomagnetic data from Tertiary magmatic rocks. Tectonophysics, **233**: 163–176.

Popescu, Gh. & Constantinescu, E. (1977): Mineralogical observations on the skarns and mineralization in Oraviţa region. Analele Universităţii Bucureşti, **26**: 45–58 (in Romanian).

Popov, P.N. (1981): Magmatectonic features of the Banat–Srednogorie Belt. Geologica Balcanica **11**: 42–73.

Popov, P.N. (1987): Tectonics of the Banat–Srednogorie Rift. Tectonophysics, **143**: 209–216.

Popov, P.N. (1995): Postsubduction Alpine metallogenic zones in the Balkan Peninsula. Geologica Macedonica, **9**: 97–101.

Popov, P.N., Berza, T. & Grubić, A. (2000): Upper Cretaceous Apuseni–Banat–Timok–Srednogorie (ABTS) Magmatic and Metallogenic Belt in the Carpathian–Balkan Orogen. In ABCD-GEODE workshop Abstracts volume, Borovets, Bulgaria, 69–70.

Rădulescu, D. & Dimitrescu, R. (1982): The endogenous petrology of Romania. Bucharest: Editura Universităţii din Bucureşti, 120 p (in Romanian).

Rădulescu, D. & Săndulescu, M. (1973): The plate-tectonics concept and the geological structure of the Carpathians. Tectonophysics, **16**:155–166.

Rădulescu, D., Săndulescu, M. & Borcoş, C.M. (1993): Alpine magmatogenetic map of Romania; an approach to the systematization of the igneous activity. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **37**: 3–8.

Roşu, E., Seghedi, I., Downes, H., Alderton, D.H.M., Szakács, Al., Pécskay, Z., Panaiotu, C., Panaiotu, C.E. & Nedelcu, L. (2004): Extension-related Miocene calc-alkaline magmatism in the Apuseni Mountains, Romania: Origin of magmas. Schweizerische Mineralogische und Petrographische Mitteilungen, **84**: 153–172.

Rumpf, J. (1874): Magnesiaglimmer von Moravitza. Mineralogische Mitteilungen, (24): 177.

Russo-Săndulescu, D. (1993): Late Cretaceous – Paleogene magmatites: the "banatites". In Ilinca, G., Marincea, Şt., Iancu, V., Russo-Săndulescu, D. & Seghedi, I: Mineral occurrences in south-western Banat. Romanian Journal of Mineralogy, **76**, Suppl. 2, 40 p.

Russo-Săndulescu, D. & Berza, T. (1979): Banatites from the western part of the Southern Carpathians (Banat), Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **23**: 149–158.

Russo-Săndulescu. D., Berza. T. & Ianc, R. (1972): The petrology of the western part of Bocşa banatitic massif. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **59**: 65–100 (in Romanian).

Russo-Săndulescu, D., Berza, T., Bratosin, I. & Ianc, R. (1978): Petrological study of the Bocşa banatitic massif (Banat). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **64**: 105–172.

Russo-Săndulescu, D., Vîjdea, E. & Tănăsescu, A. (1984): Neocretaceous – Paleogene subduction igneous rocks in the Romanian Carpathians — mutual relationships, succession and areal distribution. Anuarul Institutului de Geologie şi Geofizică, **64**: 111–119.

Russo-Săndulescu, D., Berza, T., Bratosin, I., Vlad, C. & Ianc, R. (1986a) Petrological study of banatites in the Ocna de Fier–Dognecea zone. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **70–71** (1): 123–142.

Russo-Săndulescu, D., Bratosin, I., Vlad, C. & Ianc, R. (1986b) Petrochemical study of the Surduc banatitic magmatites (Banat). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **70–71** (1): 97–121.

Russo-Săndulescu, D., Vîjdea, E. & Tănăsescu, A. (1986c) Significance of K-Ar radiometric ages obtained in the banatitic plutonic area of Banat. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **70–71** (1): 405–417.

Rusu, A.A. (2008): St. Nicholas Church and the Noble Residence of the Arceşti Family in Densuş (Hunedoara County). Arheologia Medievală, **7**: 121–224 (In Romanian, with English extended abstract).

Rusu, A. & Burnichioiu, I. (2008): Medieval monuments from Haţeg District. Cluj-Napoca: Editura Mega, 64 p.

Savu, H., Maier, O., Serafimovici, V., Mîndroiu, V., Neguţ, Gh. & Andăr, P. (1977): The mineralogy, geochemistry and formation of pyrite and arsenopyrite mineralization at Văliug (Southern Carpathians). Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **63**: 71–104 (in Romanian).

Săndulescu, M. (1984): Geotectonics of Romania. Bucharest: Editura Tehnică, 336 p (in Romanian).

Săndulescu, M. (1994): Overview on Romanian geology. In Berza, T. (ed.): ALCAPA II, Geological evolution of the Alpine–Carpathian–Pannonian system. Field Guidebook: Southern Carpathians and Apuseni Mountains Romania. Romanian Journal of Tectonics and Regional Geology, **75** (Suppl. 2): 3–15.

Săndulescu, M. & Visarion, M, (2000): Crustal structure and evolution of the Carpathian–Western Black Sea areas. First Break, **18**: 103–108.

Săndulescu, M., Kräutner, H., Borcoş, M., Năstăseanu, S., Patrulius, D., Ştefănescu, M., Ghenea, C., Lupu, M., Savu, H., Bercia, I. & Marinescu, F. (1978): Geological map of Romania, 1:1,000,000. Bucharest: Institute of Geology and Geophysics.

Schuller, V., Frisch, W., Danisik, M., Dunkl, I. & Melinte, M.C. (2009): Upper Cretaceous Gosau deposits of the Apuseni Mountains (Romania) – similarities and differences to the Eastern Alps. Austrian Journal of Earth Sciences, **102**: 133–145.

Stanisheva-Vassileva, G. (1980): The Upper Cretaceous magmatism in Srednogorie Zone, Bulgaria: a classification attempt and some implications. Geologica Balcanica, **10**: 15–36.

Ştefan, A. (1980): Petrographic study of the eastern part of the Vlădeasa eruptive massif. Anuarul Institutului de Geologie şi Geofizică, **55**: 207–325.

Ştefan, A., Istrate, G. & Medeşan, A. (1978): Gehlenite in calc-skarns from the Măgureaua Vaţei – Cerboaia (Apuseni Mountains – Romania). Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **22**: 155–160.

Ştefan, A., Lazăr, C., Berbeleac, I. & Udubaşa, G. (1985): Upper Cretaceous – Paelogene magmatites (banatites) in the Apuseni Mountains (Romania). Proceedings of the 8th Congress of the Carpatho-Balkan Geological Association, Krakow, Poland, 126–128.

Ştefan, A., Lazăr, C., Berbeleac, I. & Udubaşa, G. (1988): Evolution of the banatitic magmatism in the Apuseni Mts. and associated metallogenesis. Dări de Seamă ale Şedinţelor – Institutul de Geologie şi Geofizică, **72–73** (2): 195–213.

Ştefan, A., Roşu, E., Andăr, A., Robu, L., Robu, N., Bratosin, I., Grabari, G., Stoian, M., Vîjdea, E. & Colios, E. (1992): Petrological and geochemical features of banatitic magmatites in Northern Apuseni Mountains. Romanian Journal of Petrology, **75**: 97–115.

Stoici, S.D. (1983): The Băiţa Bihorului metallogenic district. Bucharest: Editura Academiei, 189 p. (in Romanian).

Stoicovici, E. & Selegean, I. (1970): Contributions to the knowledge of the banatitic magmatism of the Bihor Mts. Studia Universitatis Babeş-Bolyai, Geologie-Mineralogie, **44** (2): 11–24 (in Romanian).

Strashimirov.S., Petrunov. R. & Kanazirski. M. (2002): Porphyry-copper mineralization in the central Srednogorie Zone, Bulgaria. Mineralium Deposita, **37**: 587–598.

Topa, D., Makovicky, E. & Balić-Žunić, T. (2003): Crystal structures and crystal chemistry of members of the cuprobismutite homologous series of sulfosalts. Canadian Mineralogist, **41**: 1481–1501.

Tschermak, G. (1874): Ludwigit, ein neues Mineral aus dem Banate. Mineralogische Mitteilungen, (24): 59–66.

Tschermak, G. (1879): Die Glimmergruppe (II). Zeitschrift für Krystallographie, **3**: 122–167.

Vlad, Ş.N. (1974): Mineralogy and genesis of the skarn deposit at Dognecea. Bucharest: Editura Academiei, 119 p (in Romanian).

Vlad, Ş.N. (1979): A survey of banatitic (Laramian) metallogeny in the Banat region. Revue Roumaine de Géologie, Géophysique, Géographie, sér. Géologie, **23**: 39–44.

Vlad, Ş.N. (1983): The geology of porphyry-copper ore deposits. Bucharest: Editura Academiei, 156 p (in Romanian).

Vlad, Ş.N. (1997): Calcic skarns and transversal zoning in the Banat mountains, Romania: indicators of an Andean-type setting. Mineralium Deposita, **32**: 446–471.

Vlad, Ş.N. & Borcoş, M. (1994): Metallogenesis and plate tectonics in Romania. In Borcoş, M & Vlad, Ş.N. (eds): Plate tectonics and metallogeny in the East Carpathians and Apuseni Mts., June 7–19, 1994, Baia Mare, Romania. IGCP No. 356. Field trip guide, 1–9, Geological Institute of Romania.

Vlad, Ş.N. & Vasiliu, C. (1969): Some chemical characteristics of the pyroxenic skarns from Dognecea, Banat, Romania. Norsk Geologisk Tidsskrift, **49**: 361–366.

Willingshofer, E. (2000): Extension in collisional orogenic belts: the Late Cretaceous evolution of the Alps and Carpathians. PhD Thesis, Vrije Universiteit, Amsterdam, The Netherlands, 146 p

Žak, L., Fryda, J., Mumme, W.G. & Paar, W.H. (1994): Makovickyite, $Ag_{1.5}Bi_{5.5}S_9$, from Băiţa Bihorului, Romania: The ^4P natural mineral member of the pavonite series. Neues Jahrbuch für Mineralogie – Abhandlungen, **168**: 147–169.

Zimmermann, A., Stein, H., Hannah, J., Koželj, D., Bogdanov, K. & Berza T. (2008): Tectonic configuration of the Apuseni–Banat–Timok–Srednogorie belt, Balkans–Southern Carpathians, constrained by high precision Re-Os molybdenite ages. Mineralium Deposita, **43**: 1–21.

Zotov, N., Kockelman, W., Jacobsen, S.D., Mitov, I., Paneva, D., Vassileva, R.D. & Bonev, I.K. (2005): Structure and cation order in manganilvaite: a combined X-ray-diffraction, neutron-diffraction and Mössbauer study. Canadian Mineralogist, **43**: 1043–1053.

Appendix 1. Minerals from occurrences visited during the field trip

(Minerals first described from these localities with **bold** lettering. Common rock forming minerals were omitted)

Băița Bihor

aikinite	$PbCuBiS_3$
aleksite	$PbBi_2Te_2S_2$
andradite	$Ca_3Fe^{3+}_2(SiO_4)_3$
apophyllite-(KF)	$KCa_4(Si_8O_{20})(F,OH) \cdot 8H_2O$
aragonite	$CaCO_3$
aschamalmite	$Pb_6Bi_2S_9$
aurichalcite	$Zn_5(CO_3)_2(OH)_6$
azurite	$Cu_3(CO_3)_2(OH)_2$
benjaminite	$(Ag,Cu)_3(Bi,Pb)_7S_{12}$
berryite	$Pb_3(Ag,Cu)_5Bi_7S_{16}$
bismite	Bi_2O_3
bismuth	Bi
bismuthinite	Bi_2S_3
bismuthinite derivatives	$Bi_2S_3 - CuPbBiS_3$
bornite	Cu_5FeS_4
brochantite	$Cu_4(SO_4)(OH)_6$
brucite	$Mg(OH)_2$
boulangerite	$Pb_5Sb_4S_{11}$
bustamite	$CaMn^{2+}Si_2O_6$
calcite	$CaCO_3$
caledonite	$Cu_2Pb_5(CO_3)(SO_4)_3(OH)_6$
cannizzarite	$Pb_4Bi_6S_{13}$
carrollite	$Cu(Co,Ni)_2S_4$
cervelleite	Ag_4TeS
cerussite	$PbCO_3$
chalcanthite	$CuSO_4 \cdot 5H_2O$
chalcocite	Cu_2S
chalcopyrite	$CuFeS_2$
chondrodite	$Mg,Fe^{2+})_5(SiO_4)_2(F,OH)_2$
chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$
chrysotile	$Mg_3Si_2O_5(OH)_4$
clinochlore	$Mg_6Si_4O_{10}(OH)_8$
clinohumite	$Mg_9(SiO_4)_4F_2$
clinozoisite	$Ca_2Al_3(Si_2O_7)(SiO_4)O(OH)$
corundum	Al_2O_3
cosalite	$Pb_2Bi_2S_5$
cobaltite	CoAsS
copper	Cu
covellite	CuS
crocoite	$Pb(CrO_4)$
cubanite	$CuFe_2S_3$
cuprobismutite	$Cu_8AgBi_{13}S_{24}$
cupromakovickyite	$Cu_4AgPb_2Bi_9S_{18}$
digenite	$Cu_{1.8}S$
diopside	$CaMgSi_2O_6$
dioptase	$CuSiO_3 \cdot H_2O$
djurleite	$Cu_{31}S_{16}$
dolomite	$CaMg(CO_3)_2$
electrum	(Au,Ag)
emplectite	$CuBiS_2$
epidote	$Ca_2Fe^{3+}Al_2(Si_2O_7)(SiO_4)O(OH)$
erythrite	$Co_3(AsO_4)_2 \cdot 8H_2O$
fletcherite	$CuNi_2S_4$
fluoborite	$Mg_3(BO_3)F_3$
fluorite	CaF_2
forsterite	$MgSiO_4$
galena	PbS
galenobismutite	$PbBi_2S_4$
gersdorffite	NiAsS
glaukosphaerite	$(Cu,Ni)_2CO_3(OH)_2$
goethite	FeO(OH)
gold	Au
goslarite	$ZnSO_4 \cdot 7H_2O$
grossular	$Ca_3Al_2(SiO_4)_3$
hammarite	$Pb_2Cu_2Bi_4S_9$
hemimorphite	$Zn_4(Si_2O_7)(OH)_2 \cdot H_2O$
hessite	Ag_2Te
heyrovskýite	$Pb_6Bi_2S_9$
hodrushite	$Cu_4Bi_6S_{11}$
hörnesite	$Mg_3(AsO_4)_2 \cdot 8H_2O$
hydromagnesite	$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$
hydrotungstite	$WO_2(OH)_2 \cdot H_2O$
hydrozincite	$Zn_5(CO_3)_2(OH)_6$
IMA2008-053	**$Cu_7Pb_{27}Bi_{25}S_{68}$**
ingodite	Bi_2TeS
joseite A	Bi_4TeS_2
joseite B	Bi_4Te_2S
junoite	$Cu_2Pb_3Bi_8S_{16}$
kotoite	$Mg_3(BO_3)_2$
kupčíkite	$Cu_{3.4}Fe_{0.6}Bi_5S_{10}$
laumontite	$CaAl_2Si_4O_{12} \cdot 4H_2O$
leadhillite	$Pb_4(SO_4)(CO_3)_2(OH)_2$
lepidocrocite	$Fe^{3+}O(OH)$
lillianite	$Pb_{3-2x}Ag_xBi_{2+x}S_6$
linarite	$PbCu(SO_4)(OH)_2$
lizardite	$Mg_3Si_2O_5(OH)_4$
ludwigite	$Mg_2Fe^{3+}O_2(BO_3)$
luzonite	Cu_3AsS_4
magnesite	$MgCO_3$
magnetite	$Fe^{2+}Fe^{3+}_2O_4$
makovickyite	$Cu_{1.12}Ag_{0.81}Pb_{0.27}Bi_{5.35}S_9$
malachite	$Cu_2CO_3(OH)_2$
maldonite	Au_2Bi
marcasite	FeS_2
maucherite	$Ni_{11}As_8$
meionite	$3CaAl_2Si_2O_8 \cdot CaCO_3$
miharaite	$PbCu_4FeBiS_6$
mimetite	$Pb_5(AsO_4)_3Cl$
molybdenite	MoS_2
natrolite	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$
nickeline	NiAs
norbergite	$Mg_3(SiO_4)(F,OH)_2$
norsethite	$BaMg(CO_3)_2$
paděraite	$Cu_7(Cu,Ag)_{0.33}Pb_{1.33}Bi_{11.33}S_{22}$
palygorskite	$(Mg, Al)_2Si_4O_{10}(OH) \cdot 4H_2O$
pararammelsbergite	$NiAs_2$
pekoite	$PbCuBi_{11}(S,Se)_{18}$
pseudomalachite	$Cu_5(PO_4)_2(OH)_4$
pyromorphite	$Pb_5(PO_4)_3Cl$

pyrophyllite	$Al_2Si_4O_{10}(OH)_2$
rosasite	$(Cu,Zn)_2(CO_3)(OH)_2$
scawtite	$Ca_7(Si_3O_9)_2(CO_3) \cdot 2H_2O$
scheelite	$Ca(WO_4)$
scolecite	$Ca(Si_3Al_2)O_{10} \cdot 3H_2O$
smithsonite	$ZnCO_3$
sphalerite	ZnS
suanite	$Mg_2(B_2O_5)$
szaibélyite	$\mathbf{MgBO_2(OH)}$
tetradymite	Bi_2Te_2S
tetrahedrite	$Cu_{12}Sb_4S_{13}$
theisite	$Cu_5Zn_5(AsO_4,SbO_4)_2(OH)_7$
tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
tyrolite	$Ca_2Cu_9(AsO_4)_4(CO_3)(OH)_8 \cdot 11H_2O$
vesuvianite	$(Ca,Na)_{19}(Al,Mg,Fe)_{13}(SiO_4)_{10}(Si_2O_7)_4(OH,F)$
vikingite	$Ag_5Pb_8Bi_{13}S_{30}$
wittichenite	Cu_3BiS_3
wollastonite	$CaSiO_3$

Pietroasa

andradite	$Ca_3Fe^{3+}_2(SiO_4)_3$
apophyllite-(KOH)	$KCa_4Si_8O_{20}(OH,F) \cdot 8H_2O$
brucite	$Mg(OH)_2$
calcite	$CaCO_3$
chlorite group	
chondrodite	$(Mg,Fe^{2+})_5(SiO_4)_2(F,OH)_2$
chrysotile	$Mg_3Si_2O_5(OH)_4$
clinochlore	$Mg_6Si_4O_{10}(OH)_8$
diopside	$CaMgSi_2O_6$
dolomite	$CaMg(CO_3)_2$
dypingite	$Mg_5(CO_3)_4(OH)_2 \cdot 5H_2O$
epidote	$Ca_2Fe^{3+}Al_2(Si_2O_7)(SiO_4)O(OH)$
forsterite	Mg_2SiO_4
goethite	$FeO(OH)$
grossular	$Ca_3Al_2(SiO_4)_3$
humite	$Mg_7(SiO_4)_3(F,OH)_2$
hydrotalcite	$Mg_6Al_2CO_3(OH)_{16} \cdot 4H_2O$
illite group	
kotoite	$Mg_3(BO_3)_2$
lepidocrocite	$Fe^{3+}O(OH)$
lizardite	$Mg_3Si_2O_5(OH)_4$
ludwigite	$Mg_2Fe^{3+}O_2(BO_3)$
magnesioferrite	$MgFe^{3+}_2O_4$
magnesite	$MgCO_3$
magnetite	$Fe^{2+}Fe^{3+}_2O_4$
periclase	MgO
phlogopite	$KMg_3(Si_3Al)O_{10}(OH)_2$
pyrophyllite	$Al_2Si_4O_{10}(OH)_2$
scheelite	$Ca(WO_4)$
sepiolite	$Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$
spinel	$MgAl_2O_4$
suanite	$Mg_2(B_2O_5)$
szaibélyite	$MgBO_2(OH)$
talc	$Mg_3Si_4O_{10}(OH)_2$
vesuvianite	$(Ca,Na)_{19}(Al,Mg,Fe)_{13}(SiO_4)_{10}(Si_2O_7)_4(OH,F,O)_{10}$
wollastonite	$CaSiO_3$
zeolite group	

Măgureaua Vaţei

åkermanite	$Ca_2MgSi_2O_7$
allophane	$Al_2O_3(SiO_2)_{1.3\text{–}2.0} \cdot 2.5\text{–}3.0H_2O$
aluminian diopside	$CaMg_{1-x}(Al,Fe^{3+})_{2x}Si_{2-x}O_6$
analcime	$Na(Si_2Al)O_6 \cdot H_2O$
andradite	$Ca_3Fe^{3+}_2(SiO_4)_3$
aragonite	$CaCO_3$
bicchulite	$Ca_2Al_2SiO_6(OH)_2$
calcite	$CaCO_3$
CaTs clinopyroxene	$CaAl_2SiO_6$
cebollite	$Ca_2(Mg,Fe^{2+},Al)Si_2(O,OH)_7$
cuspidine	$Ca_4Si_2O_7F_2$
djerfisherite	$K_6NaFe_{24}S_{26}Cl$
ellestadite	$Ca_{10}(SiO_4)_3(SO_4)_3(OH,F)_2$
esseneite	$CaFe^{3+}AlSiO_6$
foshagite	$Ca_4(SiO_3)_3(OH)_2$
gehlenite	$Ca_2Al(SiAl)O_7$
gismondine	$Ca_2(Si_4Al_4)O_{16} \cdot 8H_2O$
grossular	$Ca_3Al_2(SiO_4)_3$
hibschite	$Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$
hydroxylellestadite	$Ca_{10}(SiO_4)_3(SO_4)_3(OH)_2$
kalsilite	$KAlSiO_4$
kamaishilite	$Ca_2(SiAl_2)O_6(OH)_2$
melilite	$Al_2C_6(COO)_6 \cdot 16H_2O$
monticellite	$CaMgSiO_4$
mountainite	$KNa_2Ca_2[Si_8O_{19}(OH)] \cdot 6H_2O$
pectolite	$NaCa_2Si_3O_8(OH)$
perovskite	$CaTiO_3$
plombierite	$Ca_5Si_6O_{16}(OH)_2 \cdot 7H_2O$
prehnite	$Ca_2Al(Si_3Al)O_{10}(OH)_2$
rankinite	$Ca_3Si_2O_7$
riversideite	$Ca_5Si_6O_{16}(OH)_2 \cdot 2H_2O$
scawtite	$Ca_7(Si_3O_9)_2(CO_3) \cdot 2H_2O$
spinel	$MgAl_2O_4$
spurrite	$Ca_5(SiO_4)_2(CO_3)$
thomsonite	$NaCa_2(Al_5Si_5)O_{20} \cdot 6H_2O$
tilleyite	$Ca_5Si_2O_7(CO_3)_2$
titanian garnet	$Ca_3(Fe^{3+},Al,Ti)_2(Si,Al,Fe^{3+})_3O_{12}$
tobermorite	$Ca_5Si_6O_{16}(OH)_2 \cdot nH_2O$
vesuvianite	$(Ca,Na)_{19}(Al,Mg,Fe)_{13}(SiO_4)_{10}(Si_2O_7)_4(OH,F,O)_{10}$
wollastonite	$CaSiO_3$
xonotlite	$Ca_6Si_6O_{17}(OH)_2$

Ocna de Fier – Dognecea

actinolite	$Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$
aikinite	$CuPbBiS_3$
andalusite	Al_2OSiO_4
andradite	$Ca_3Fe^{3+}_2(SiO_4)_3$
anglesite	$PbSO_4$
ankerite	$CaFe^{2+}(CO_3)_2$
antigorite	$Mg_3Si_2O_5(OH)_4$
apatite	$Ca_5(PO_4)_3F$
aragonite	$CaCO_3$
arsenopyrite	$FeAsS$
aurichalcite	$Zn_5(CO_3)_2(OH)_6$
azurite	$Cu_3(CO_3)_2(OH)_2$
baryte	$BaSO_4$
bismuth	Bi
bismuthinite	Bi_2S_3
bismuthinite derivatives	$Bi_2S_3\text{–}CuPbBiS_3$

bismutite	$Bi_2O_2(CO_3)$
bohdanowiczite	$AgBiSe_2$
bornite	Cu_5FeS_4
brochantite	$Cu_4SO_4(OH)_6$
brucite	$Mg(OH)_2$
calcite	$CaCO_3$
carrollite	$CuCo_2S_4$
cerussite	$PbCO_3$
chalcocite	Cu_2S
chalcopyrite	$CuFeS_2$
chrysotile	$Mg_3Si_2O_5(OH)_4$
clinochlore	$Mg_6Si_4O_{10}(OH)_8$
clinohumite	$Mg_9(SiO_4)_4F_2$
clinozoisite	$Ca_2Al_3(Si_2O_7)(SiO_4)O(OH)$
cobaltpentlandite	Co_9S_8
copper	Cu
cordierite	$Mg_2Al_4Si_5O_{18}$
corundum	Al_2O_3
cosalite	$Pb_2Bi_2S_5$
covellite	CuS
cuprite	Cu_2O
cuprobismutite	$Cu_8AgBi_{13}S_{24}$
cupromakovickyite	$Cu_4AgPb_2Bi_9S_{18}$
digenite	$Cu_{1.8}S$
diopside	$CaMgSi_2O_6$
dolomite	$CaMg(CO_3)_2$
electrum	(Au,Ag)
emplectite	$CuBiS_2$
epidote	$Ca_2Fe^{3+}Al_2(Si_2O_7)(SiO_4)O(OH)$
eulytine	$Bi_4(SiO_4)_3$
felbertalite	$Cu_2Pb_6Bi_8S_{19}$
fluorite	CaF_2
forsterite	Mg_2SiO_4
friedrichite	$Cu_5Pb_5Bi_7S_{18}$
galena	PbS
galenobismutite	$PbBi_2S_4$
gladite	$CuPbBi_5S_9$
goethite	FeO(OH)
gold	Au
greenockite	CdS
grossular	$Ca_3Al_2(SiO_4)_3$
gypsum	$CaSO_4 \cdot 2H_2O$
hedenbergite	$CaFe^{2+}Si_2O_6$
hedleyite	Bi_7Te_3
hematite	Fe_2O_3
hemimorphite	$Zn_4Si_2O_7(OH)_2 \cdot H_2O$
hessite	Ag_2Te
heyrovskýite	$Pb_6Bi_2S_9$
hodrushite	$Cu_4Bi_6S_{11}$
jamesonite	$Pb_4FeSb_6S_{14}$
kaolinite	$Al_2Si_2O_5(OH)_4$
kawazulite	$Bi_2(Te,Se,S)_3$
krupkaite	$PbCuBi_3S_6$
lepidocrocite	$Fe^{3+}O(OH)$
lillianite	$Pb_{3-2x}Ag_xBi_{2+x}S_6$
lindströmite	$Pb_3Cu_3Bi_7S_{15}$
linnaeite	Co_3S_4
lizardite	$Mg_3Si_2O_5(OH)_4$
ludwigite	**$Mg_2Fe^{3+}O_2(BO_3)$**
magensioferrite	$MgFe^{3+}_2O_4$
magnetite	$Fe^{2+}Fe^{3+}_2O_4$
makovickyite	$Cu_{1.12}Ag_{0.81}Pb_{0.27}Bi_{5.35}S_9$
malachite	$Cu_2CO_3(OH)_2$
manganilvaite	$CaFe^{2+}Fe^{3+}Mn^{2+}(Si_2O_7)O(OH)$
manjiroite	$Na(Mn^{4+},Mn^{2+})_8O_{16} \cdot nH_2O$
marcasite	FeS_2
matildite	$AgBiS_2$
mawsonite	$Cu_6Fe_2SnS_8$
molybdenite	MoS_2
neyite	$Ag_2Cu_6Pb_{25}Bi_{26}S_{68}$
nuffieldite	$Cu_{1.4}Pb_{2.4}Bi_{2.4}Sb_{0.2}S_7$
paděraite	$Cu_7(Cu,Ag)_{0.33}Pb_{1.33}Bi_{11.33}S_{22}$
palygorskite	$(Mg,Al)_2Si_4O_{10}(OH) \cdot 4H_2O$
phlogopite	$KMg_3(Si_3Al)O_{10}(OH)_2$
pseudomalachite	$Cu_5(PO_4)_2(OH)_4$
pyrite	FeS_2
pyroaurite	$Mg_6Fe^{3+}_2CO_3(OH)_{16} \cdot 4H_2O$
pyrolusite	MnO_2
pyrrhotite	Fe_7S_8
rhodochrosite	$MnCO_3$
rhodonite	$Mn^{2+}SiO_3$
siderite	$FeCO_3$
silver	Ag
sphalerite	ZnS
stibnite	Sb_2S_3
szaibélyite	$MgBO_2(OH)$
tetradymite	Bi_2Te_2S
tetrahedrite	$Cu_{12}Sb_4S_{13}$
todorokite	$(Na,Ca,K,Ba,Sr)_{1-x}(Mn,Mg,Al)_6O_{12} \cdot 3–4H_2O$
tourmaline group	
tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
valeriite	$2[(Fe,Cu)S] \cdot 1.53[(Mg,Al)(OH)_2]$
vesuvianite	$(Ca,Na)_{19}(Al,Mg,Fe)_{13}(SiO_4)_{10}(Si_2O_7)_4(OH,F,O)_{10}$
veszelyite	**$Cu^{2+}_3PO_4(OH)_3 \cdot 2H_2O$**
volynskite	$AgBiTe_2$
wittichenite	Cu_3BiS_3
wollastonite	$CaSiO_3$

Oravița – Ciclova

afwillite	$Ca_3(SiO_3)_2(OH)_2 \cdot 2H_2O$
alloclase	**CoAsS**
allophane	$Al_2O_3(SiO_2)_{1.3-2.0} \cdot 2.5–3.0H_2O$
analcime	$Na(Si_2Al)O_6 \cdot H_2O$
andradite	$Ca_3Fe^{3+}_2(SiO_4)_3$
apophyllite	$KCa_4Si_8O_{20}F \cdot 8H_2O$
arsenopyrite	FeAsS
aurichalcite	$Zn_5(CO_3)_2(OH)_6$
azurite	$Cu_3(CO_3)_2(OH)_2$
baryte	$BaSO_4$
bismite	Bi_2O_3
bismuth	Bi
bismuthinite derivatives	Bi_2S_3 – $CuPbBiS_3$
bornite	Cu_5FeS_4
calcite	$CaCO_3$
cannizzarite	$Pb_8Bi_{10}S_{23}$
chalcocite	Cu_2S
chalcopyrite	$CuFeS_2$
chondrodite	$(Mg,Fe^{2+})_5(SiO_4)_2(F,OH)_2$
chrysotile	$Mg_3Si_2O_5(OH)_4$
clinochlore	$Mg_6Si_4O_{10}(OH)_8$

clinozoisite	$Ca_2Al_3(Si_2O_7)(SiO_4)O(OH)$
clintonite	$CaAlMg_2(SiAl_3)O_{10}(OH)_2$
cobaltite	$CoAsS$
copper	Cu
cordierite	$Mg_2Al_4Si_5O_{18}$
corundum	Al_2O_3
cosalite	$Pb_2Bi_2S_5$
covellite	CuS
cubanite	$CuFe_2S_3$
cuprite	Cu_2O
cupromakovickyite	$Cu_4AgPb_2Bi_9S_{18}$
digenite	$Cu_{1.8}S$
diopside	$CaMgSi_2O_6$
electrum	(Au,Ag)
ellestadite	$Ca_{10}(SiO_4)_3(SO_4)_3(OH,F)_2$
emplectite	$CuBiS$
enargite	Cu_3AsS_4
epidote	$Ca_2Fe^{3+}Al_2(Si_2O_7)(SiO_4)O(OH)$
erythrite	$Co_3(AsO_4)_2 \cdot 8H_2O$
felbertalite	$Cu_2Pb_6Bi_8S_{19}$
fluorite	CaF_2
forsterite	Mg_2SiO_4
galena	PbS
galenobismutite	$PbBi_2S_4$
gehlenite	$Ca_2Al(SiAl)O_7$
gersdorffite	$NiAsS$
goethite	$FeO(OH)$
gold	Au
grossular	$Ca_3Al_2(SiO_4)_3$
hematite	Fe_2O_3
hemimorphite	$Zn_4Si_2O_7(OH)_2 \cdot H_2O$
hörnesite (TL ?)	$\mathbf{Mg_3(AsO_4)_2 \cdot 8H_2O}$
hydrotungstite	$WO_2(OH)_2 \cdot H_2O$
ingodite	Bi_2TeS
junoite	$Cu_2Pb_3Bi_8S_{16}$
kilchoanite	$Ca_6(SiO_4)(Si_3O_{10})$
kupčíkite	$Cu_{3.4}Fe_{0.6}Bi_5S_{10}$
laumontite	$CaAl_2Si_4O_{12} \cdot 4H_2O$
lepidocrocite	$Fe^{3+}O(OH)$
lillianite	$Pb_{3-2x}Ag_xBi_{2+x}S_6$
löllingite	$FeAs_2$
luzonite	Cu_3AsS_4
mackinawite	$(Fe,Ni)_{1+x}S$
magnetite	$Fe^{2+}Fe^{3+}_2O_4$
makovickyite	$Cu_{1.12}Ag_{0.81}Pb_{0.27}Bi_{5.35}S_9$
malachite	$Cu_2CO_3(OH)_2$
marcasite	FeS_2
meionite	$3CaAl_2Si_2O_8 \cdot CaCO$
molybdenite	MoS_2
monticellite	$CaMgSiO_4$
nickeline	$NiAs$
perovskite	$CaTiO_3$
phlogopite	$KMg_3(Si_3Al)O_{10}(OH)_2$
proudite	$Cu_2Pb_{16}Bi_{20}S_{47}$
pyrite	FeS_2
pyrrhotite	Fe_7S_8
scheelite	$Ca(WO_4)$
scorodite	$Fe^{3+}AsO_4 \cdot 2H_2O$
siderite	$Fe^{2+}CO_3$
silver	Ag
skutterudite	$CoAs_{3-x}$
sphalerite	ZnS
spinel	$MgAl_2O_4$
spurrite	$Ca_5(SiO_4)_2(CO_3)$
stibnite	Sb_2S_3
stilbite	$NaCa_4(Si_{27}Al_9)O_{72} \cdot 28H_2O$
talc	$Mg_3Si_4O_{10}(OH)_2$
tellurobismuthite	Bi_2Te_3
tenorite	CuO
tetradymite	Bi_2Te_2S
tetrahedrite	$Cu_{12}Sb_4S_{13}$
thomsonite	$NaCa_2(Al_5Si_5)O_{20} \cdot 6H_2O$
tilleyite	$Ca_5Si_2O_7(CO_3)_2$
tourmaline group	
tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
vesuvianite	$(Ca,Na)_{19}(Al,Mg,Fe)_{13}(SiO_4)_{10}(Si_2O_7)_4(OH,F)$
vikingite	$Ag_5Pb_8Bi_{13}S_{30}$
wittichenite	Cu_3BiS_3
wollastonite (TL of "table spar")	$\mathbf{CaSiO_3}$

Moldova Nouă

allophane	$Al_2O_3(SiO_2)_{1.3-2.0} \cdot 2.5–3.0H_2O$
analcime	$Na(Si_2Al)O_6 \cdot H_2O$
anhydrite	$CaSO_4$
anthophyllite	$Mg_7Si_8O_{22}(OH)_2$
aragonite	$CaCO_3$
aurichalcite	$Zn_5(CO_3)_2(OH)_6$
azurite	$Cu_3(CO_3)_2(OH)_2$
bayldonite	$Cu_3PbO(AsO_3OH)_2(OH)_2$
bornite	Cu_5FeS_4
boulangerite	$Pb_5Sb_4S_{11}$
bournonite	$CuPbSbS_3$
brochantite	$Cu_4[(OH)_6\|SO_4]$
calcite	$CaCO_3$
cerussite	$PbCO_3$
chabazite-Ca	$Ca(Si_4Al_2)O_{12} \cdot 6H_2O$
chalcanthite	$CuSO_4 \cdot 5H_2O$
chalcoalumite	$CuAl_4SO_4(OH)_{12} \cdot 3H_2O$
chalcocite	Cu_2S
chalcophyllite	$Cu_{18}Al_2(AsO_4)_4(SO_4)_3(OH)_{24} \cdot 36H_2O$
chalcopyrite	$CuFeS_2$
chlorite group	
chondrodite	$Mg_5(SiO_4)_2F_2$
chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$
copper	Cu
covellite	CuS
cuprite	Cu_2O
cyanotrichite	$\mathbf{Cu_4Al_2SO_4(OH)_{12} \cdot 2H_2O}$
dickite	$Al_2Si_2O_5(OH)_4$
diopside	$CaMgSi_2O_6$
epidote	$Ca_2Fe^{3+}Al_2(Si_2O_7)(SiO_4)O(OH)$
euchroite	$Cu_2AsO_4(OH) \cdot 3H_2O$
fluorite	CaF_2
galena	PbS
garnet group	
geocronite	$Pb_{14}(Sb,As)_6S_{23}$
goslarite	$ZnSO_4 \cdot 7H_2O$
gypsum	$CaSO_4 \cdot 2H_2O$
hematite	Fe_2O_3
kaolinite	$Al_2Si_2O_5(OH)_4$

"limonite"	$FeO(OH) \cdot nH_2O$	sepiolite	$Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$
ludwigite	$Mg_2Fe^{3+}O_2(BO_3)$	smithsonite	$ZnCO_3$
magnetite	$Fe^{2+}Fe^{3+}_2O_4$	sphalerite	ZnS
malachite	$Cu_2CO_3(OH)_2$	stevensite	$(Ca,Na)_xMg_3Si_4O_{10}(OH)_2$
marcasite	FeS_2	stilbite-Ca	$NaCa_4(Si_{27}Al_9)O_{72} \cdot 28H_2O$
melanterite	$Fe^{2+}SO_4 \cdot 7H_2O$	susannite	$Pb_4(SO_4)(CO_3)_2(OH)_2$
molybdenite	MoS_2	tenorite	CuO
montmorillonite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$	tetradymite	Bi_2Te_2S
orpiment	As_2S_3	tetrahedrite	$Cu_{12}Sb_4S_{13}$
pyrite	FeS_2	thomsonite-Ca	$NaCa_2(Al_5Si_5)O_{20} \cdot 6H_2O$
pyrrhotite	Fe_7S_8	vivianite	$Fe^{2+}_3(PO_4)_2 \cdot 8H_2O$
realgar	AsS	wollastonite	$CaSiO_3$

Appendix 2. – Itinerary for IMA2010 RO5 Field trip

Saturday, August 28, 2010 (Day 1) – total distance 388 km

08.00–12.00 Travel from Budapest to Beiuş (*via* Albertirsa, Szolnok, Ártánd, Oradea)
12.00–13.00 Lunch break in Beiuş
13.30–14.30 Brief presentation of Băiţa Bihor mine at S.C. Băiţa HQ in Ştei
15.00–19.00 Field stop 1: Skarns and mineralization at Băiţa Bihor
19.00–19.30 Travel to Beiuş
Dinner and accommodation in Beiuş

Sunday, August 29, 2010 (Day 2) – total distance 329 km

08.00–08.45 Travel to Pietroasa
08.45–09.30 Field stop 2: Magnesian borates in the skarns of Dealul Gruiului – Pietroasa
90.30–11.00 Travel to Măgureaua Vaţei
11.00–12.30 Field stop 3: High-temperature calcic skarns at Cornet Hill and Cerboaia Valley (Măgureaua Vaţei area)
12.30–13.00 Travel to Brad
13.00–14.00 Lunch break in Brad
14.00–15.00 Field stop 4: The Museum of Gold, Brad
15.00–16.30 Travel to Sântămăria Orlea
16.30–17.00 Field stop 5: St. Mary's church, 13th century - Sântămaria Orlea
17.00–17.30 Travel to Densuş
17.30–18.00 Field stop 6: Densuş Church – 13th century
18.00–18.30 Travel to Sarmizegetusa
18.30–19.00 Field stop 7: Ulpia Traiana Sarmizegetusa – the Roman capital city of Dacia, 2nd and 3rd centuries
19.00–21.00 Travel to Bocşa
Dinner and accommodation in Bocşa

Monday, August 30, 2010 (Day 3)– total distance 45 km

08.00–08.15 Travel to banatite outcrop in Bocşa
08.15 – 08.45 Field stop 8: Banatite outcrop, Bocşa
08.45 – 09.00 Travel to Ocna de Fier
09.00–10.30 Field stop 9: Gruescu mineralogical collection, Ocna de Fier
10.30–12.00 Field stop 10: The skarn deposit at Ocna de Fier. Ursoanea waste dump
12.00–12.10 Travel to Bocşa

12.30–13.30	Lunch break in Bocşa
13.30–14.00	Travel to Ocna de Fier
14.00–15.00	Field stop 11: The skarn deposit at Ocna de Fier. Terezia quarry
15.00–16.00	Walk to Iuliana quarry
16.00–17.30	Field stop 12: The skarn deposit at Ocna de Fier. Iuliana quarry
17.30–18.30	Walk back to Ocna de Fier and travel to Bocşa

Dinner and accommodation in Bocşa

Tuesday, August 31, 2010 (Day 4) –total distance 215 km

08.00–09.30	Travel to Oraviţa
09.30–10.30	Field stop 13: The skarn occurrence in Ogaşul Crişenilor Oraviţa
10.30–11.00	Travel to Ciclova
11.00–12.30	Field stop 14: The skarns and banatites in Ţiganilor Valley, Ciclova
12.30–13.30	Travel to Moldova Nouă
13.30–14.30	Field stop 15: The porphyry copper ore deposit at Suvorov, Moldova Nouă
14.30–17.00	Travel to Eşelniţa. Sightseeing and geological transect across Danube Gorges

Farewell dinner and accommodation in Eşelniţa

Wednesday, September 1, 2010 (Day 5) – total distance 517 km

8.00–17.00	Travel to Budapest.